An Assessment of the Potential for the Sustainable Development of the Edible Periwinkle, *Littorina littorea*, Industry in Ireland

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ACKNOWLEDGEMENTS

SECTION 1 - INTRODUCTION

1 Background to the Study and Project Objectives

The edible periwinkle *Littorina littorea* (L.) has been exploited as a food source in Ireland since the stone age (Woodman, Anderson and Finlay, 1999). Today there is a large market for the edible periwinkle on the continent, principally in France. Pearson (1994) estimated that the Irish periwinkle industry was worth approximately €6.34 million (£5 million) in exports per annum. The edible periwinkle industry remains a fishery of economic and sociological importance in peripheral coastal communities. It is particularly important as an additional source of income in areas where few other employment opportunities exist.

According to the Department of Marine and Natural Resources (DoMNR), 2,635 tonnes of periwinkles were exported in 1998. However, this is considered by some to be a gross underestimate of the size of the industry. Unofficial figures provided by a wholesaler at the 1997 Shellfish Association AGM, suggested that, at the time, closer to 7,000 tonnes were exported per annum.

The difficulty in assessing the true scale of the Irish periwinkle industry lies in its black market nature. In addition, periwinkles are a “non-pressure stock” species which means that the fishery is completely unregulated. Indeed, many wholesalers claim that over-harvesting of the resource is jeopardising the recruitment of periwinkles on our shores.

Prior to this study, there was little or no scientific information available on the state of Irish periwinkle stocks, nor was there an accurate estimate of the scale and value of the Irish industry. This project aimed to redress this situation.

The main objectives of the project were:

- To establish the distribution and abundance of the edible periwinkle populations along the Irish coast and to provide a benchmark against which subsequent studies could be compared.

- In reviewing the Irish periwinkle industry, to assess its socio-economic impact on Irish coastal communities and to determine the potential impact of developments within this sector.

- To incorporate the resultant data into a Geographical Information System (GIS). The GIS would then be used as a decision making tool in developing a management strategy for the industry.

Primary field workers were Ms. Valerie Cummins and Ms. Orla McClean (both from the Coastal and Marine Resources Centre, National University of Ireland, Cork), and Ms. Susan Coughlan (from the Shellfish Research Laboratory, National University of Ireland, Galway). Ms. Cummins took over from Ms. McClean in June 1999. Field sites along the coast were arbitrarily split in two, with the Shannon estuary as the point of division. Ms. Coughlan was responsible for sampling and interviewing relevant individuals north of this point (i.e. County Clare to County Donegal), and Ms. Cummins and Ms McClean south and east of this point (i.e. County Kerry to County Louth), including regular sampling of Bullens Bay in

County Cork. Regular meetings were scheduled to ensure continuity of methods and exchange of ideas. Several other research assistants were employed at various stages of the project to aid with sampling and measurement of animals.

Plate 1. The edible periwinkle, *Littorina littorea.*

SECTION 2 - OVERVIEW OF PERIWINKLE BIOLOGY

2 Overview of Periwinkle Biology

2.1 Anatomical description

The edible periwinkle, *Littorina littorea* (Linnaeus, 1758), is a Prosobranch gastropod of the Family Littorinacea. It is one of the most common, and one of the largest, shore Gastropods of the Irish coast. It can attain a height of approximately 35cm. The head and tentacles of the animal are covered with dense transverse black lines; in some individuals, the head and tentacles are uniformly black. Sexes are separate and easily distinguished (at least when the animals are ripe) by the presence of a penis on the right hand side of the male and a whitish ovipositor in the equivalent area of the female. Under certain conditions, including the presence of the anti-fouling pollutant tributyltin (TBT), females may show abnormal development of a penis (pseudohermaphroditism) (Casey, *et al*., 1996).

Mature shell height ranges from approximately 10.6mm – 52.8mm (Reid, 1996). The shell is usually dark brown, and can appear almost black when wet. Other shell colours such as pale cream and orange occur occasionally. The outer lip of the aperture is defined by brown lines. The columella is white (except in old animals, where it may discolour to a darker cream). Juvenile *L. littorea* are more difficult to identify. They have a crenulated shell, and may be mistaken for the rough periwinkle, *Littorina rudis.* A particularly distinguishing feature of *L. littorea* is the alternate light and dark banding on the outer lip of the shell (Fish and Fish, 1989).

2.2 Distribution

L. littorea is distributed from the White Sea (and perhaps Spitzbergen) to Southern Portugal in the eastern Atlantic, and in the western Atlantic from Labrador to Virginia. The rapid spread of *L. littorea* along the northwestern Atlantic coast, following human settlement in North America in the nineteenth century, provides one of the most well documented examples of the dispersal of marine species (Reid, 1996).

The species is common around the coast of Ireland, Britain, the Outer Hebridies, Orkneys and Shetland Islands (Smith and Newell, 1955; Reid, 1996). However, it is rare on certain small offshore islands, including the Isles of Scilly (Smith & Newell, 1955), Lundy and St Kilda (see Reid, 1996). This has been attributed to probable low rates of colonization by planktotrophic larvae from mainland populations, and the difficulty in maintaining populations where endogenous larvae may be swept away by currents (Reid, 1996).

L. littorea is typically found on rocky shores, where its vertical range extends from high water neap tide level to extreme low water spring tide level (Moore, 1937). Occasionally it may occur sub-littoraly to depths of approximately 60m (Fretter and Grahame, 1960). The vertical level at which periwinkles may be found on the shore is variable and depends on factors such as exposure and weed cover (Lubchenco, 1983). Food scarcity appears to set the upper limit to the vertical distribution of *L. littorea* (Yamada and Mansour, 1987). While *L. littorea* is found mainly on semi-exposed to sheltered coasts, it is also tolerant of estuarine conditions and great exposure (Boulding and Alstyne, 1993; Fish, 1972; Williams, 1964).

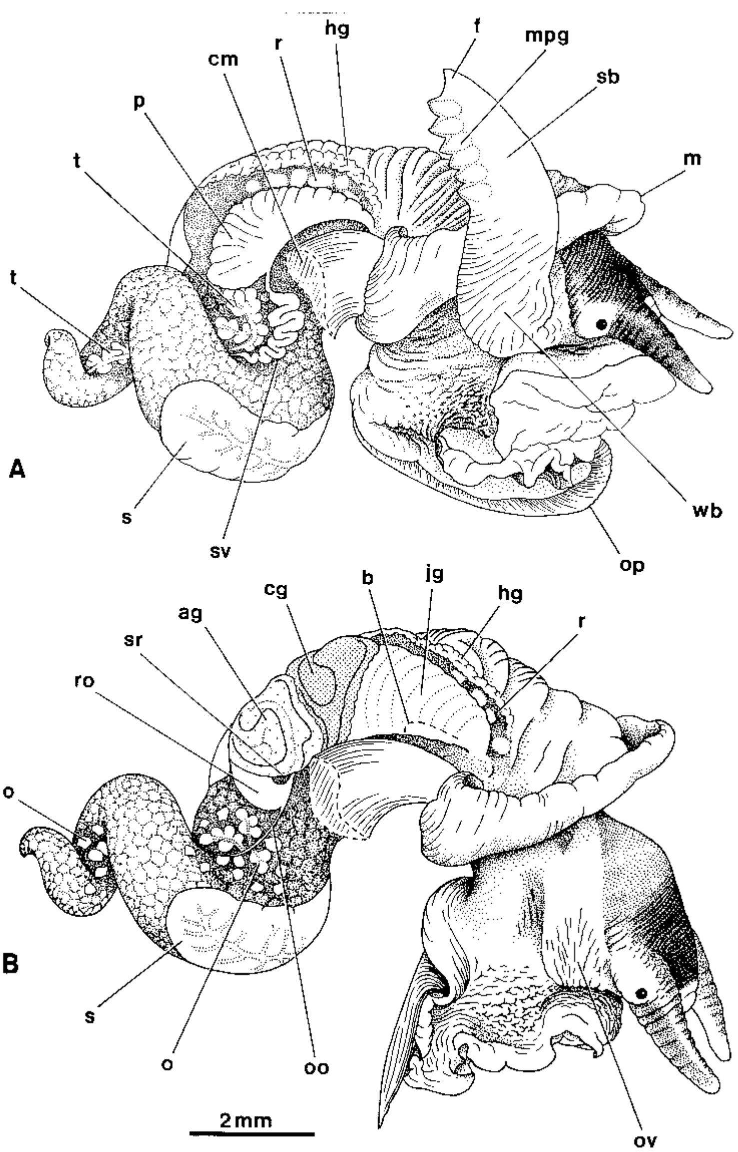


Figure 1. **A mature male (A) and female (B) of a representative littorinid (*Littorina compressa*) the anatomy of which closely resembles that of *L. littorea*.** This diagram from **Reid (1996)** is more accurate and representative than the diagram from Fretter and Grahame (1968). The animals are removed from their shell and undissected. Abbreviations: ag albumen gland, b, copulatory bursa (visible by dissection); cg, capsule gland; cm, insertion of columelllar muscle on shell; f, filament of penis; hg, hypobranchial gland; jg, jelly gland; m, mantle edge; mamillliform penial gland (visible by transparency); o, ovary (ramifying in digestive gland); oo, ovarian oviduct; op, operculum; ovipositor; prostate gland; rectum; ro, renal oviduct; s, stomach; sb, smooth region of penial base; sr, sv, seminal vesicle; t, testis (ramifying in digestive gland); wb, wrinkled region of penial base.

2.3 Spawning and development

Gastropods living on rocky shores exhibit a wide range of reproductive strategies and patterns of embryonic and larval development (Underwood and McFayden, 1983). Within the Family Littorinacea, different species show different methods of reproduction, ranging from direct development in benthic egg capsules (e.g. *L. mariae*, Fretter and Graham, 1962), to ovoviviparity (e.g. *L. saxatilis,* Berry, 1961), to pelagic eggs and planktotrophic larvae (e.g. *M. neritoides,* Lebour, 1935; *L. unifasciata*, Underwood and Chapman, 1989).

A detailed account of the male and female reproductive systems of *L. littorea* has been given by Linke (1933), and is summarised by Fretter and Graham (1962). Williams (1964) distinguished five development stages (which he described for each sex): immature virgin, maturing individuals/recovering spents, fully mature and spawning, partially spent, and spent (Table 1). This method has been adopted by several authors to enable comparison between different populations (Fish 1972; O Sullivan 1977; Doyle 1993).

Maturity is thought to occur 12-18 months after settlement once a shell height of approximately 11mm has been reached (Williams, 1964). Populations of *L. littorea* vary in their time of spawning. Even at the same latitude; maturation, copulation and spawning times show wide local variations depending on food availability and exposure (Fish, 1972). Breeding and spawning in Irish and UK populations occurs from January to June, (Tattersall, 1920; Moore, 1937; Williams, 1964; Fish 1972, 1979). A fortnightly rhythm of egg release related to the tidal cycle was suggested by Grahame (1975), and conclusively demonstrated by Alifierakis & Berry (1980), following experiments in the UK.

Fertilisation is internal, after which, the females release planktonic egg capsules. These egg capsules are pelagic, asymmetrically biconvex with a flat peripheral rim. The egg capsules contain a maximum of nine eggs (Linke, 1933); more commonly, they contain one to three (Thorson, 1946; Fish, 1979). Upon release, the egg capsules swell osmotically and burst after five to six days. Each egg hatches into a free-swimming veliger larva and remains in this planktonic stage for six to seven weeks. This planktotrophic development stage results in widespread dispersal and genetic uniformity. Metamorphosis may be delayed if conditions are not suitable. This results in considerable variation of settlement times, with larvae settling on the shore throughout several months of the year.

Table 1. Female and male development stages of *L. littorea* (after Williams, 1964).

Females

Stage	Ovipositor	Gonad	Caps gland/ albumen gland	Covering gland
Stage I Immature	Heavily pigmented	No trace	Vestigial	Vestigial
Stage II Maturing	Lightly pigmented	Diffuse light pink areas	Small but distinct	Small but distinct
Stage II Recovering	Lightly pigmented	Extensive light pink areas	Large, often swollen, yellow-brown	Dark brown
Stage III Ripe	Lightly pigmented and well defined	Very extensive light pink areas	Very swollen, white	Dark brown
Stage IV Partially spent	Lightly pigmented	Extensive; dark pink/red	Slightly swollen, yellow-cream	Very dark brown
Stage V Spent	Heavily pigmented	Scarce, red or red/brown areas	Poorly developed, Dark yellow brown	Poorly developed, yellow brown

Males

Stage	Penis	Vas deferens	Prostate	Gonad
Stage I Immature	Minute	No trace	Faint trace	No trace
Stage II Maturing	Very small	Lightly coiled, possibly with some sperm	Distinct	Scattered yellow areas
Stage II recovering	Quite well developed	Lightly coiled, possibly with some sperm	Distinct	Extensive light yellow
Stage III Ripe	Large	White, much coiled, swollen; full of sperm	Well developed, cream-white	Very extensive, light yellow
Stage IV Partially spent	Well developed	Much coiled, not swollen, sperm in lower coils	Distinct, yellow-brown	Extensive, yellow-brown
Stage V Spent	Very small	Gently coiled, dark brown	Small, dark brown	Poorly developed, localised dark brown areas only

2.4 Diet and feeding

L. littorea is an omnivorous grazer. However, it is highly selective in favour of the foliose ephemeral green algae *Ulva lactuca* and *Enteromorpha intestinalis*. The fucoid *Ascophyllum nodosum* and *Coralinia officinalis* are rejected even after prolonged periods of starvation. These algae are not readily digestible; the latter species is heavily calcified and presents a physical barrier to grazing. In addition, drift algal material is frequently exploited as a food source (Watson and Norton, 1985), especially at higher shore levels (Woodbridge, 1978).

Feeding activity is influenced by tidal cycle and season. The animals are stimulated to feed when immersed by the tide and when damp conditions prevail (Newell, 1958; Moore, 1936; Williams, 1964). The grazing activity of periwinkles can have a habitat modifying impact on a shore. The grazing process removes sediment from hard substrates which precludes the development of an algal canopy (Bertness, 1984). At high densities, *L. littorea* can clear shores of *Enteromorpha* sp. and can inhibit settlement of barnacles *Balanus* sp. (Petratis, 1983).

2.5 Growth

Growth rate is defined as the change in body mass or weight over time. *L. littorea* shows considerable variation in growth rate for the first four years of its life. Shell height is the commonly employed measure of growth. Fretter and Graham (1962) describe shell formation in two major phases: 1) cellular processes of ion transport, protein synthesis, and secretion, and 2) a series of photochemical processes in which crystals of Calcium Carbonate (CaCo3) are nucleated, orientated, and grow in intimate association with a secreted organic matrix. Through growth, mineralised granules form rounded flattened crystals, each covered by a delicate organic membrane. The layering of the crystals appear as striations to the naked eye. Each spiral grows around and partly conceals the surface of the previous whorl. Thus, the most recently secreted part of the shell is that by the mouth. Where the inner sides of the spirally coiled whorls are brought into contact with on another, there results a more or less solid pillar, the columella, around which the whorls of the shell rotate (Fretter and Graham, 1962).

A shell height of approximately 8-9mm is achieved by the end of the first year (Williams, 1964). This increases to about 16mm by the end of the third year. A pattern in growth rates was observed by Lambert & Farley (1968), and by Gardener and Thomas (1987). The general trend was for growth rates to increase from May to early July, followed by a decrease in growth rates from mid-July to mid-August. Growth rates were observed to increase again in early September, before declining in the winter months. Although *L. littorea* are capable of breeding all year round, periods of shell growth are interrupted when conditions are favourable for reproduction (Williams, 1964). For example, Williams (1964) observed active shell growth on a shore in Wales, from July to October, which corresponded with a period when mature animals were fully spent. Growth rates decreased when gonad maturation began again the following November. However, Fretter and Graham (1960) observed a looser growth cycle, when, on reaching sexual maturity a cessation in growth occurred in correspondence with a period of maximum sexual activity.

The growth rate decreases rapidly with age (Fretter and Grahame, 1960) and absolute growth rate is affected by food availability and habitat (Moore 1937; Williams, 1964, Griffin, 2000).

Parasite infection and predation also affect growth and survival. Population density can affect growth rates in natural populations, with competition for resources acting to limit growth at higher values. Griffin, (2000) found exceptionally high growth rates (K = 0.0277 per 21 day period), on a high density, semi-exposed shore in Southern Ireland. The mid-shore region exhibited the highest growth rate. The lowest growth rates were found on the lower shore. Griffin (2000) concluded that periwinkles have an opportunistic growth strategy, which is attributed to competition, food availability and quality. High population densities can also prevent re-settlement of a food source. At high densities, *L. littorea* can clear shores of *Enteromorpha* sp. and can inhibit settlement of barnacles *Balanus* sp. (Petratis, 1983).

2.6 Migration

Gendron (1977) showed some evidence for a seasonal migration on a shore in North America. The periwinkle population density at the uppermost station established during his study showed a decrease in density between October and January, while an increase at the same station occurred during early summer. Gendron (1977) attributed this change in density to a shoreward spring migration. Williams and Ellis (1975), recorded similar patterns for a population in Yorkshire; however, Smith and Newell (1955), while studying a shore in Kent, suggested that periwinkles tend to remain at the beach level they adopt during the first year of life after larval settlement. *L. littorea* also show evidence of a "homing instinct", whereby dislodged individuals have the ability to find their way back to the zone from which they were displaced (Newel, 1958). Wave action is considered to be the most likely stimulus by which the animals orient themselves (Gendron, 1977).

2.7 Life span and maximum size

Periwinkles are capable of a long life as shown by Woodward's (1913) record of an individual that had reached more than 20 years in an aquarium. The largest recorded specimen came from Scotland and was 52.8mm in height (Reid 1996).

SECTION 3 - RESOURCE ASSESSMENT

3.1 Introduction

High density *L. littorea* shores are attractive sites for periwinkle harvesting activities. The harvesting of this gastropod provides a valuable source of income to rural coastal communities (Pearson, 1994). However, little is known about the impact of such harvesting activities on periwinkle populations. Wholesalers and pickers have reported problems of over-picking in the past on several shores around the country (T. Tobin, *pers. comm.,* 2000), leading to fears that the sustainability of the industry may be in jeopardy. Up until now, there was no scientific information on the distribution or density of *L. littorea* populations in Ireland.

Data collected for this study from 1998 to 2000 are examined in this chapter with a view: to describing the distribution and abundances of *L.littorea* on Irish shores; to describing the size and dynamics of periwinkles within these populations; and to providing a benchmark against which subsequent studies could be compared. Studies were also undertaken to identify some of the factors that impact on both individuals and populations of *L. littorea.*

Bullens Bay is situated on the north-westerly corner of the Old Head of Kinsale, on the County Cork coastline. It is harvested throughout the year by approximately five local pickers, however, harvesting activities are most intensive during the winter period there. The site was selected as a re-survey site to observe temporal changes in population dynamics of *L. littorea.* Bullens Bay is a sheltered site, protected from the prevailing south-westerly winds. The intertidal zone extends downwards over a gently sloping gradient. It is largely a rocky foreshore, with a small sandy beach that is exposed during low tide. Observed fauna during surveys included typical rocky foreshore species, the major components being the limpet *Patella vulgata*, the flat periwinkle *Littorina littoralis*, the dog whelk *Nucella lapillus*, and the topshells *Monodonta lineata* and *Gibbula umbilicalis*. The main source of food of the browsing species is provided by large algae, (such as *Fucus* sp. and *Ascophyllum nodosum*), as well as various microscopic algae.

3.2 Research Methods

3.2.1 Materials and methods for shore surveys

A total of 124 shores around the coast were surveyed during the project. Survey sites were selected (after consultation with wholesalers, fisheries officers and harvesters), on the basis that they provide suitable habitats for harvestable quantities of periwinkles; these were usually sheltered or semi-exposed shores. Other sites were selected (e.g. exposed coasts) for comparative purposes. In the present study, a survey site is described as an area of coast with homogenous shore type with respect to rock form, seaweed cover, exposure etc. This sometimes led to discrete sites existing along a lengthy section of shoreline.

All shores were surveyed on spring tide. At each site three belts of approximately 30m width, chosen randomly, were divided into three biologically defined zones representing upper, middle and lower shores: (i) *Fucus spiralis* to *Ascophyllum nodosum*; (ii) *A. nodosum* to *F. serratus;* (iii) *F. serratus* to the low water level.

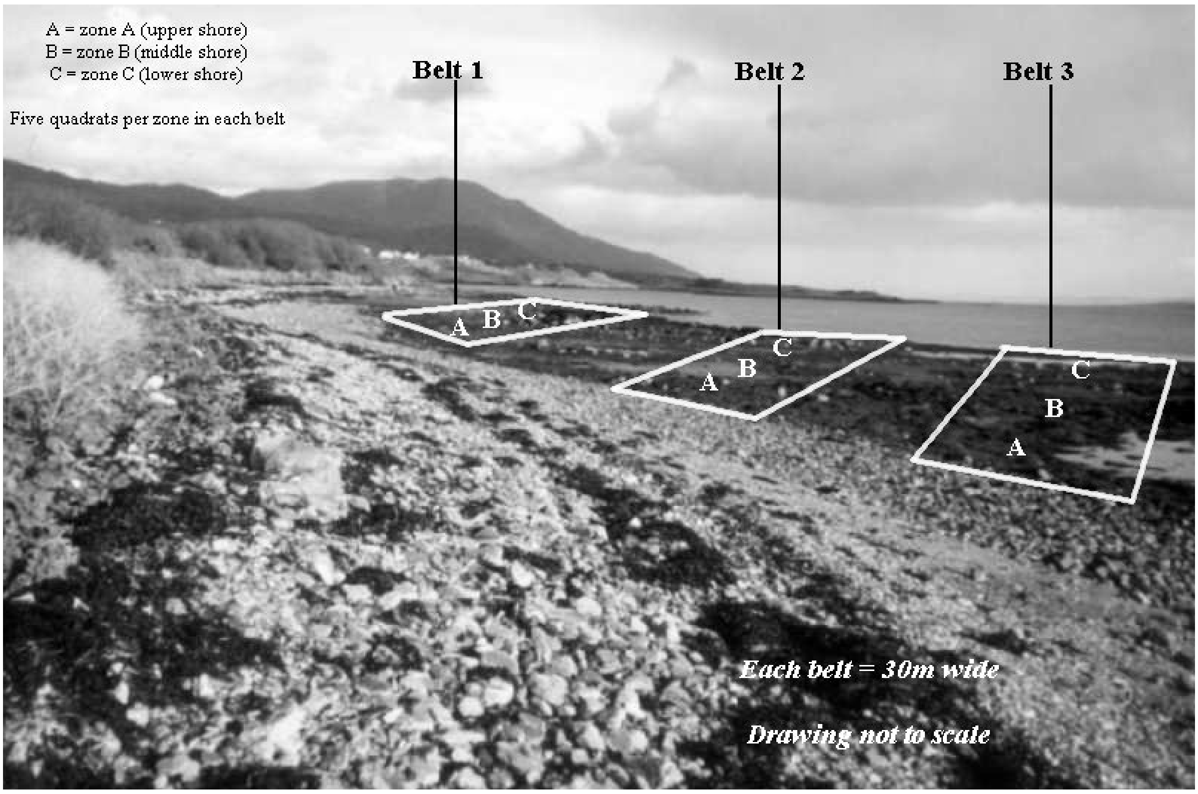


Figure 2. Example of the sampling procedure used on the shore. At each site, three belts of approximately 30m width, chosen randomly, were divided into three biologically defined zones representing upper, middle and lower shores: (i) *Fucus spiralis* to *Ascophyllum nodosum*; (ii) *A. nodosum* to *F. serratus;* (iii) *F. serratus* to the low water level.

The length of each of the three belts was measured. The bearing of each belt was also recorded. A handheld Global Positioning System (GPS) was used to mark the starting point of each belt, in addition to the start and end point for each site. This, and other relevant data were subsequently added to a Geographical Information System (GIS). GIS software facilitates the storing, manipulating and displaying of a wide range of temporal and spatial data. The maps used for this report were produced using Arcview GIS software. On completion of the study a copy of the Periwinkle Project GIS was made available to the Marine Institute in Dublin (Appendix B).

Exposure of sites was rated on a scale of one to five, after Lewis (1964) (Appendix A). One represents very exposed sites, and five represents very sheltered sites. In some cases, the exposure scale was subdivided to allow more flexibility in describing shores. As a result, there were ten possible degrees of exposure i.e. 1, 1.5, 2, 2.5 etc. (a modified version of the Lewis (1964) scale). Five quadrats ($0.25m^2$) were placed randomly within each zone and all *L. littorea* within the quadrat were counted, removed, and placed in labelled polythene bags. The samples were returned to the laboratory and frozen to preserve them for further analysis.

The percentage cover of rockpool, seaweed, bedrock, rock, stones, gravel, sand and mud was also recorded from each quadrat. Any influx of freshwater into the belt, or any other potential impact from sewage or shellfish culture was noted.

A comparison was made between the numbers of *L. littorea* on different substrate types, as recorded during the surveys, using the Chi-squared test. Substrate types included bedrock, rock, stone, gravel, sand and mud.

3.2.2 Temporal variation in density at Bullens Bay in County Cork

Bullens Bay in County Cork was selected for several re-surveys in order to assess temporal variations in periwinkle distributions on the shore. The survey method used was the same as the method described in Section 3.2.1. Table 2 shows when surveys were undertaken. Eleven re-surveys were undertaken at Bullens Bay.

Table 2. Survey dates at (a) Bullens Bay, County Cork

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1998			x					x			x	
1999	x			x				x		x	x	
2000				x				x			x	

3.2.3 Shell measurements of L. littorea

In order to investigate shell morphometry and the effects of environmental variables on shell shape at various sites, frozen samples collected from surveyed shores were measured to 0.1mm using vernier callipers. Periwinkles less than 5mm were recorded as such and were not measured. This was due to the physical difficulty of handling such small animals and due to the increased significance of any errors of measurement at such sizes (Crothers, 1992). Three measurements of each shell were taken: shell length (SL), shell width (SW), aperture length (AL). Aperture width (AW) was also measured for a number of samples. In total 6,056 periwinkles were measured for shell height, width and aperture height. In addition, 1,795 periwinkles were measured for aperture width.

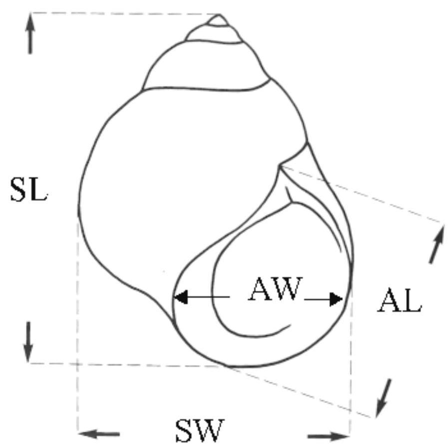


Figure 3. Morphological measurements recorded from shells. SL= Shell length; SW = Shell Width; AL = Aperture Length; AW = Aperture Width. After Reid (1996).

All statistical analysis was carried out using SPSS version 9.0. Graphs were plotted using SPSS or Excel 5.0. Error bars on all graphs where mean data is presented represent the 95% confidence interval. Non-parametric statistical tests were applied due to the bi-modal nature of the data. Spearman rank correlations were used to determine what, if any, relationships exist between the physical/ biological parameters studied and shell shape. The main factors examined for associated effect with shell morphometry in this study were:

1. Exposure
2. Vertical position on the shore (i.e. zone).

While only two factors are considered in this analysis, it is very likely that many other factors also impact on various aspects of shell shape, particularly predation (Robertson, 1992) and salinity (Reid, 1996).

3.2.4 Length frequency histograms

Histograms of shell length/frequency were plotted with the aim of investigating patterns in recruitment, growth and various aspects of population dynamics. Forty-seven sites were used for this purpose and measurements from all periwinkles >5mm shell length were used. Periwinkles <5mm shell height were excluded due to the difficulty of measuring aperture length accurately on very small shells. (However, measurements of shell height were taken from (n= 12) shells <5mm, prior to the methodology being finalised, the results of which were included in this analysis).

Bullens Bay, County Cork, was selected as a re-survey site to observe temporal changes in the length frequency distribution of the population. Bullens Bay was surveyed 11 times (Table 2). Measurements were taken from data collected from six of the 11 visits due to time constraints in measuring all of the samples. The six visits covered the period from November 1998 to August 2000. The months selected represent the months of November, January, April, August (twice) and October. Size frequency histograms were plotted from this data. The measurement data were used to examine changes in growth rates.

3.3 Results

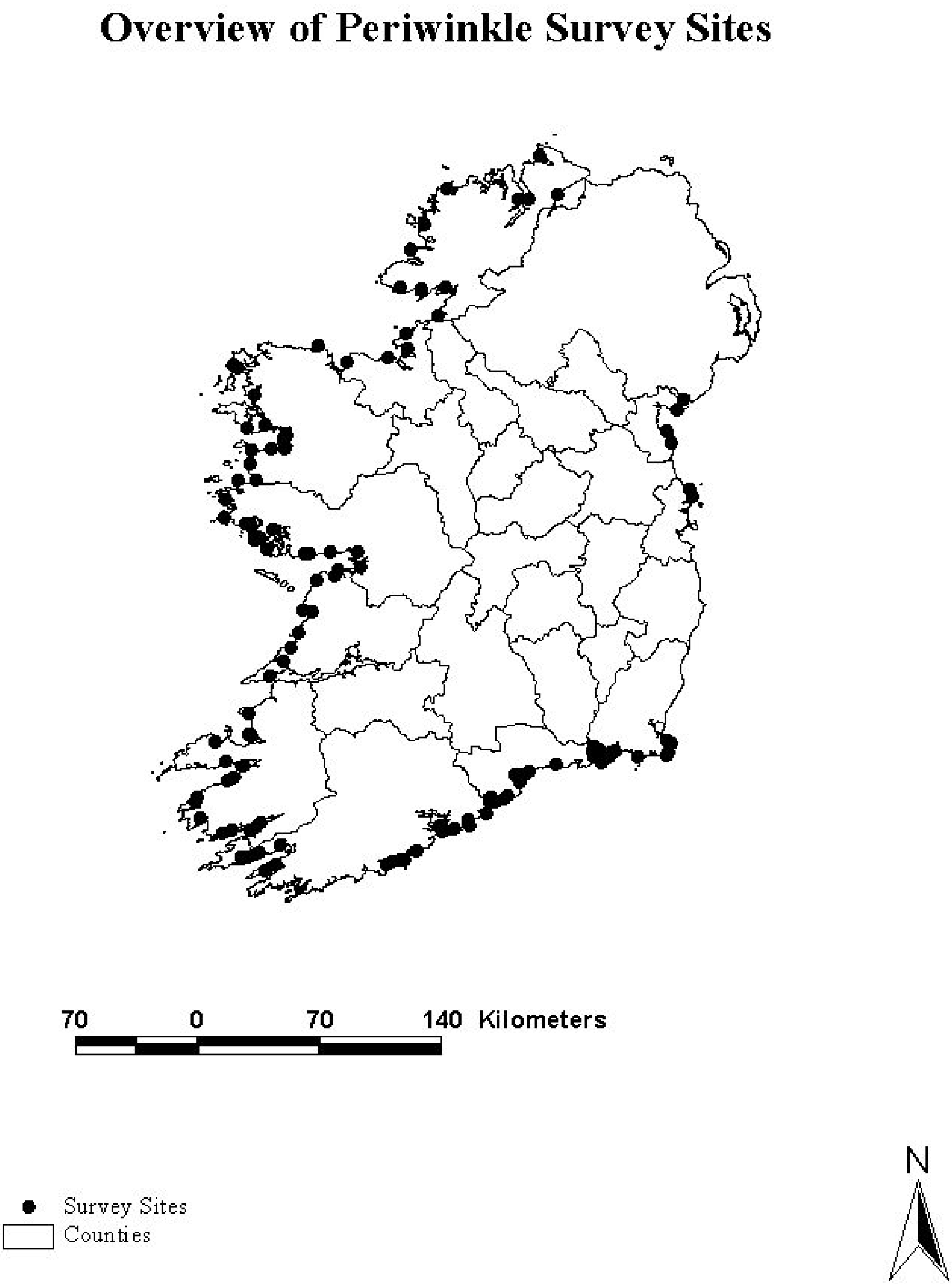


Figure 4. Overview of locations of periwinkle survey sites.

3.3.1 Results of shore surveys

Table 3. Mean periwinkle densities per m^2 at all survey sites. Exposure is based on the modified Lewis (1964) scale.

Site	County	Exposure	Mean periwinkle density per m^2
Bullens Bay	Cork	4	63
Oysterhaven	Cork	4	94
Howes Strand	Cork	1	58
Roches Point	Cork	3	69
Garrettstown	Cork	3	23
Ballycotton Island	Cork	3	31
Ballycotton	Cork	3	64
Knockadoon	Cork	3	161
Whitegate Bay	Cork	5	37
Broadstrand	Cork	4	110
Dinish Island	Cork	4	39
Ballyshane strand	Cork	2	112
Trabolgan	Cork	3	47
Youghal Town	Cork	2	8
Ardnahinch	Cork	3	104
Ballynakilla	Cork	4	52
Rocks NE of Fort Point	Cork	4	86
Aghabeg	Cork	5	48
Seal Harbour	Cork	3	121
Rocks NE of Reen Point	Cork	4	89
Reenabulliga	Cork	4	116
Kilcrohane	Cork	2	124
Whiting Bay	Waterford	3	50
Whiting Bay 2	Waterford	3	196
Ardmore Strand	Waterford	3	182
Clonea strand	Waterford	3.5	180
Helvick head - N side	Waterford	3.5	71
Ballynacourty - E side	Waterford	3	47
Youghal-East	Waterford	4	45
Ardmore East	Waterford	3	115
Dungarvan West	Waterford	5	16
Dungarvan East	Waterford	5	16
Dungarvan - Abbeyside	Waterford	4	75
Dunmore East	Waterford	5	93
Passage East	Waterford	5	38
Passage East 2	Waterford	5	26
Boatstrand	Waterford	2.5	1
Duncannon	Wexford	3	26
Duncannon 2	Wexford	3	22
Netherton	Wexford	2.5	15
Kilmore Quay	Wexford	3	15
Grange Strand	Wexford	3	24
Carnivan Bay	Wexford	3	9
Fethard Quay	Wexford	4	10

Site	County	Exposure	Mean periwinkle density per m^2
Bannow	Wexford	4	26
Patricks Bay	Wexford	2.5	69
Crossfintan Point	Wexford	3	26
Rosslare Harbour	Wexford	4	74
Greenore Point	Wexford	2	49
Ormonds Island	Kerry	4	91
Fenit 1	Kerry	4.5	26
Cromane	Kerry	4	9
Anascaul	Kerry	2.5	116
Fenit 2	Kerry	5	53
Ballyheige	Kerry	2.5	46
Fermoyle	Kerry	4	11
Glanlough	Kerry	4	38
Cove Harbour	Kerry	4	58
Ballinskelligs	Kerry	2	78
Doulus Bay	Kerry	3	49
Rossbeigh	Kerry	3	34
West of Rossbeigh	Kerry	3	47
Knightstown	Kerry	4	10
Tuosist Castle	Kerry	3	42
Loughaunacreen	Kerry	3	47
Eyeries	Kerry	2	74
Carlingford Lough	Louth	5	70
Rathcor	Louth	3	54
Corstown Bridge	Louth	2	73
Near Clogher Head	Louth	2	106
Skerries	Dublin	1.5	70
Rush	Dublin	2.5	124
Quilty	Clare	3.5	5
Fanore	Clare	2	3
Ballyvaughan	Clare	4.5	9
Doonbeg	Clare	4	19
Poulnasherry	Clare	5	6
Rehy	Clare	4	20
Lehinch	Clare	3	9
Haggs Head	Clare	2.5	19
Finavara Point	Clare	4	17
Murrisk	Mayo	5	1
Achill Sound	Mayo	4	3
Gubinwee	Mayo	3.5	15
Mullranny	Mayo	3	16
Louisburg	Mayo	2.5	22
Salleen Bay	Mayo	4	30
Roonagh Point	Mayo	2.5	31
Claggan Cove	Mayo	4.5	8

Table 3 contd. Mean periwinkle densities per m^2 at all survey sites. Exposure is based on the modified Lewis (1964) scale.

Site	County	Exposure	Mean periwinkle density per m^2
Bunlough Point	Mayo	3	26
Carrowholly	Mayo	4.5	5
Ballycastle	Mayo	2.5	35
Outer Belmullet	Mayo	2.5	19
Shellfish Laboratory, Carna	Galway	5	16
Mweenish	Galway	3	26
Loughaconeera	Galway	5	8
Letterard	Galway	4	53
Ervallagh	Galway	3	28
Finish (inside island)	Galway	4	16
Garumna Island	Galway	3.5	16
Inveran	Galway	3.5	34
Bundoran	Donegal	3.5	21
Fahan	Donegal	4.5	13
Rossbeg	Donegal	3	29
Rathmullan	Donegal	3.5	17
Meenlaragh	Donegal	3	34
Burtonpoint	Donegal	4.5	7
Doagh Isle	Donegal	2	2
Lough Foyle	Donegal	4.5	17
Kilcar	Donegal	3	62
Iniscrone	Sligo	3	14
Aughris Head	Sligo	4	39
Rosses Point	Sligo	4.5	8
Pollmolasha	Sligo	2.5	48

Table 3 contd. Mean periwinkle densities per m^2 at all survey sites. Exposure is based on the modified Lewis (1964) scale.

- Substrate data

Bedrock and stones were the most common substrate types found to occur on the surveyed shores (total percentage coverage of bedrock was 41%, percentage coverage of stones was 18%) (Figure 5). A comparison of the substrate data from different sites showed a significant relationship between gravel and periwinkle numbers, with higher numbers of periwinkles occurring on gravel sites than on other substrate types (Chi-sq value 26.67, $P<0.001$). Thus, in tests for comparisons of densities of *L. littorea* from replicated gravel sites, results indicated that the presence of gravel can have a significant influence on the densities of *L. littorea* on a shore. Results from the other Chi-squared tests were not significant. The resulting values were: *bedrock P = .817; rock P = .133; stone P = .051; sand P = .891.*

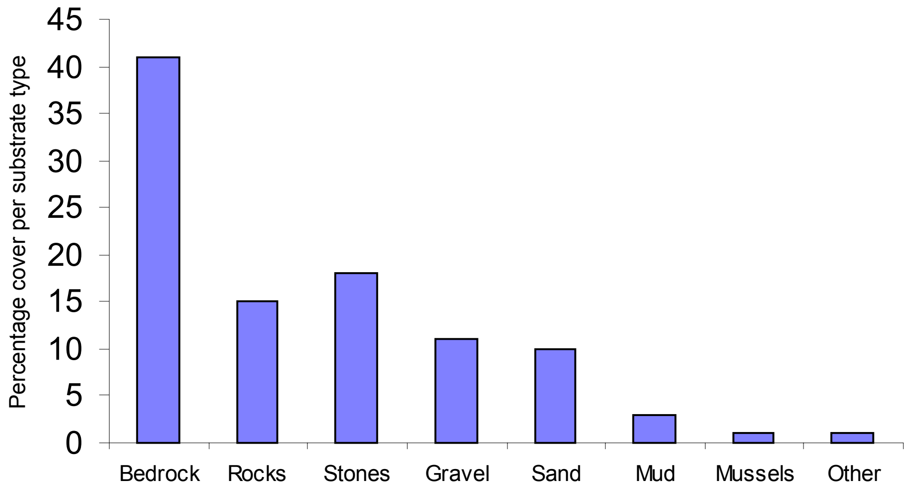


Figure 5. Total percentage cover of different substrate types recorded during the survey.

- Density and exposure

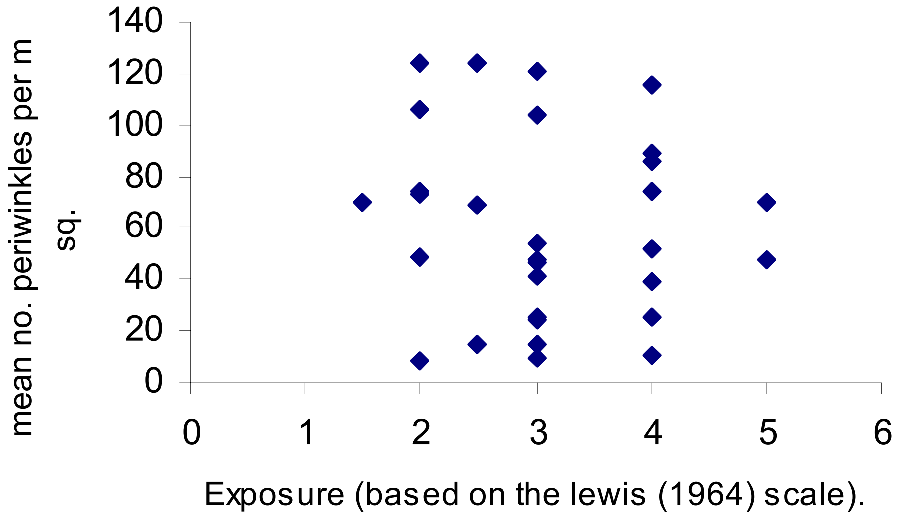


Figure 6. The relationship between density and exposure in *L. littorea* based on the mean number of perwinkles per site. The sites have different exposure levels classified according to the Lewis (1964) scale of exposure.

An examination of periwinkle densities at the study sites, indicate that in general the greatest densities of *L. littorea* occurred on shores of exposure 2-4 as defined by the Lewis (1964) scale (Figure 6). It should be noted that density decreases at the extremes of the exposure scale.

- Shoreline distributions

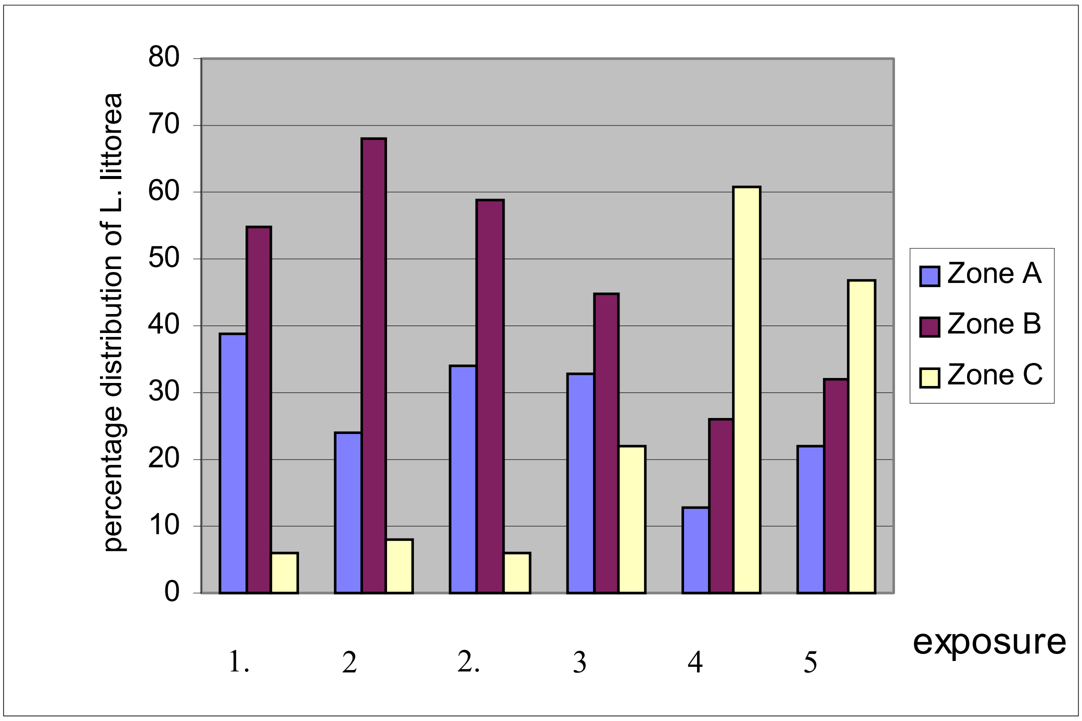


Figure 7. Percentage distribution of *L. littorea* on different levels of the shore in relation to exposure (using the modified Lewis scale).

L. littorea appear to show marked changes in preferred tidal height with exposure. This trend was noted during sampling. A graph of distribution at various exposures is presented in Figure 7. There is a reasonably consistent increase in relative density at higher shore levels on more exposed coasts. This is particularly clear in Zone C, which is the lowest of the three vertical divisions, where the percentage distribution falls from between 50% and 60% on extremely sheltered and sheltered shores, to less than 10% on exposed shores (2.5 to 1.5 on the Lewis (1964) scale of exposure).

3.3.2 Temporal variation in density at Bullens Bay in County Cork

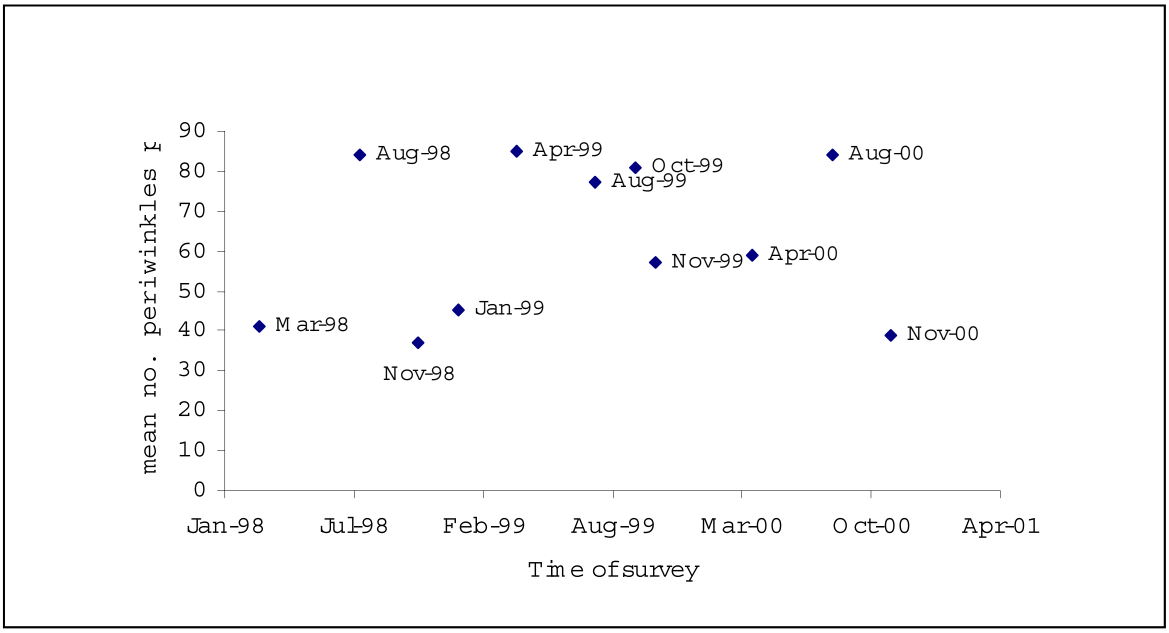


Figure 8. Changes in the mean numbers of periwinkles per m^2, over a three year period, at Bullens Bay, as recorded at different sampling times.

The shore at Bullens Bay was observed to have a mean density of *L. littorea* over the study period, of approximately 63 per m^2. There were sizeable differences in density at Bullens Bay between the sampling times, with a definite rise in densities between April and October in all three years (Figure 8). The numbers of *L. littorea* on the shore fell by over 50% between August and November in 1998 and in 2000. In 1999, periwinkle densities fell from a mean number of 81 periwinkles per m^2 in October, to 57 periwinkles per m^2 in November.

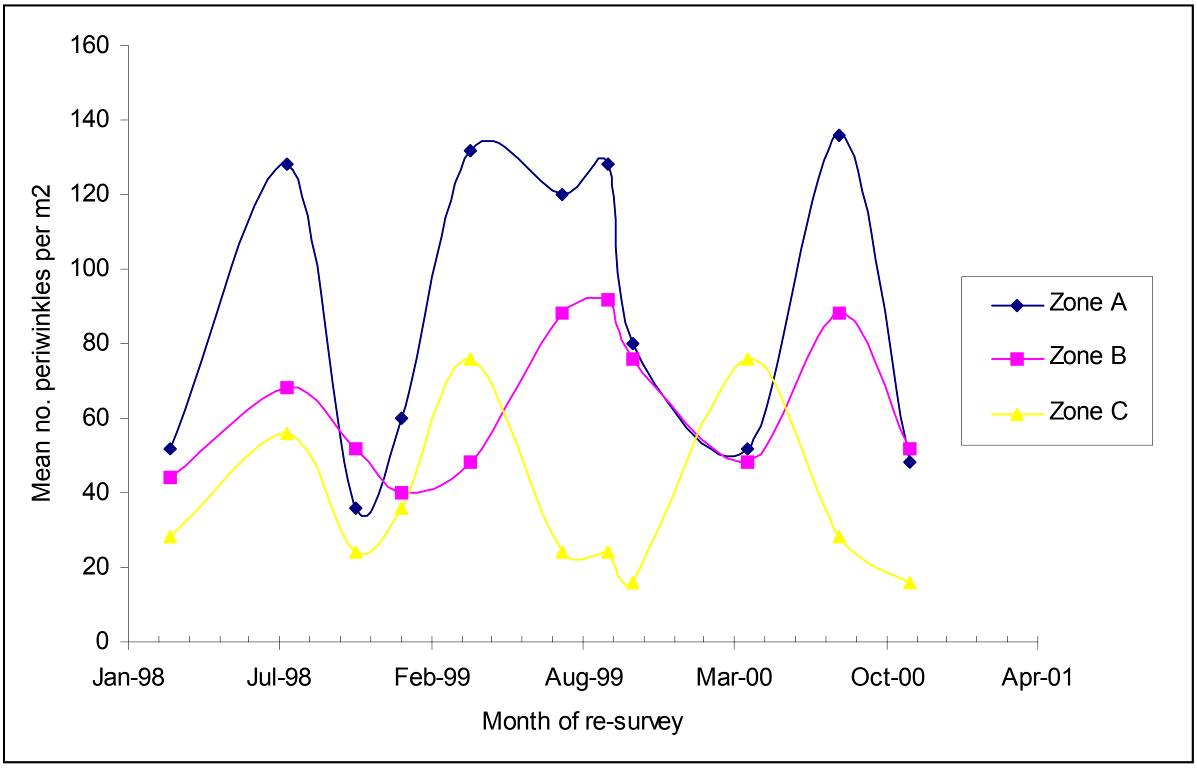


Figure 9. Mean densities of *L. littorea* on the upper, middle and lower shore at Bullens Bays over a three year period.

Densities of *L. littorea* per zone over the three year sampling period are shown in Figure 9. It can be seen from this graph that the highest numbers of periwinkles were found at the upper shore levels (zones A and B). April 1999 and April 2000 were the only periods when the number of periwinkles at the lower shore level (zone C) were observed to be higher than the number of periwinkles higher up the shore.

3.3.3 Shell measurements of L. littorea

- Exposure and shell morphometry

Results from a Spearman rank correlation show a weak correlation between shell length and exposure ($P>0.05$). The correlation between shell width and exposure is significant ($P<0.05$). These relationships are presented graphically in Figures 10 and 11.

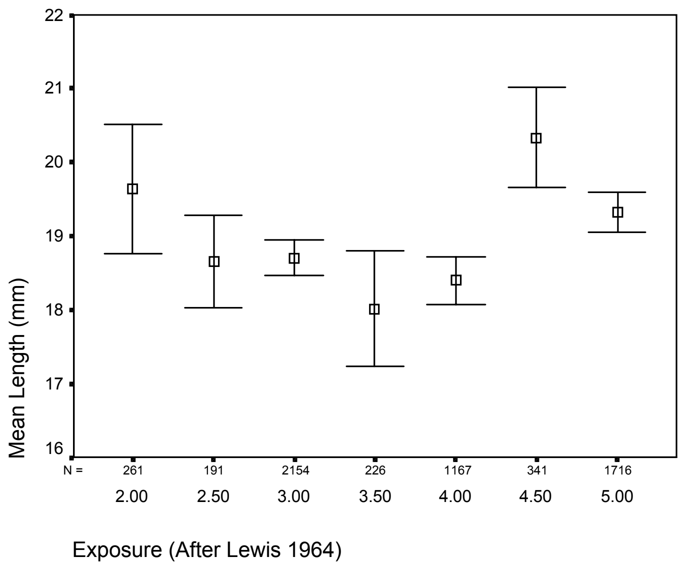


Figure 10. Relationship between mean shell length and exposure in *L. littorea*. Error bars represent the 95% confidence interval.

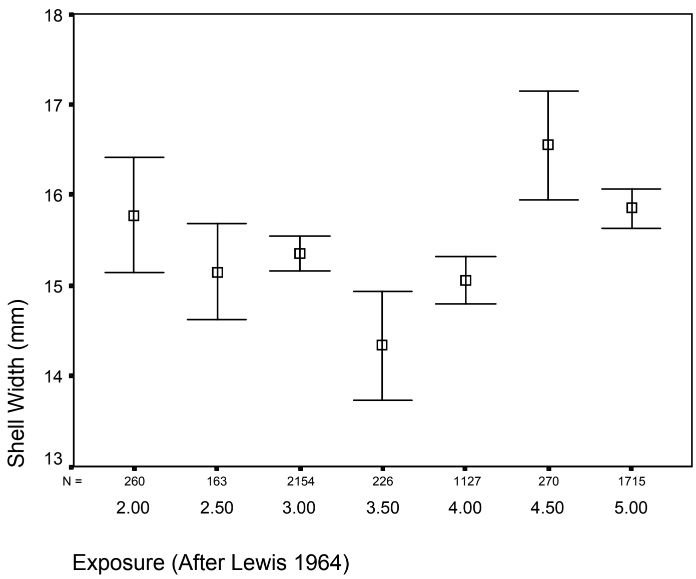


Figure 11. Relationship between mean shell width and exposure in *L. littorea*. Error bars represent the 95% confidence interval.

The relationship between exposure and mean shell height/ aperture height ratio is significant($P<0.01$). The relationship between mean shell height to aperture height ratio and exposure is shown graphically in Figure 12.

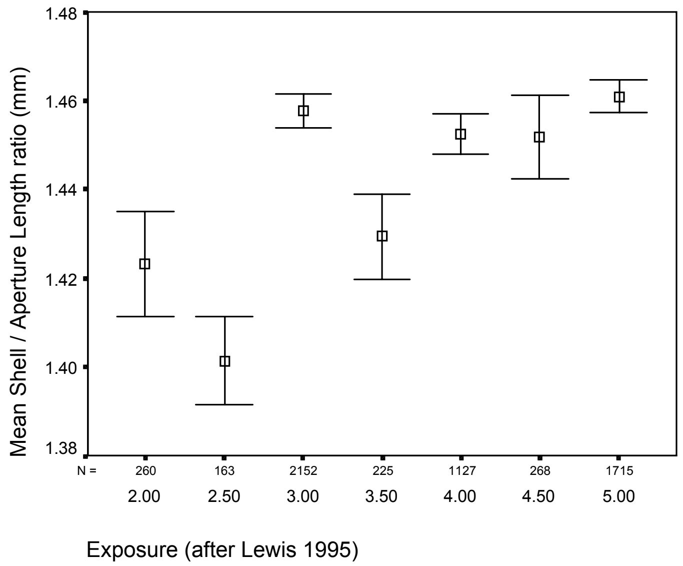


Figure 12. Relationship between mean shell height/ aperture height ratio and exposure in *L. littorea*. Error bars represent the 95% confidence interval.

- Vertical position (zone) and shell morphometry

Zone A represents the upper shore, zone B represents the middle shore and zone C represents the lower shore. The Spearman rank correlations between zone/height, zone/width and zone/aperture height/shell height ratio are significant at the 0.01 level for each parameter. It can be seen from Figure 13 that there is a distinct increase in shell height at lower shore levels. Figure 14 shows that relative aperture height decreases at lower shore levels.

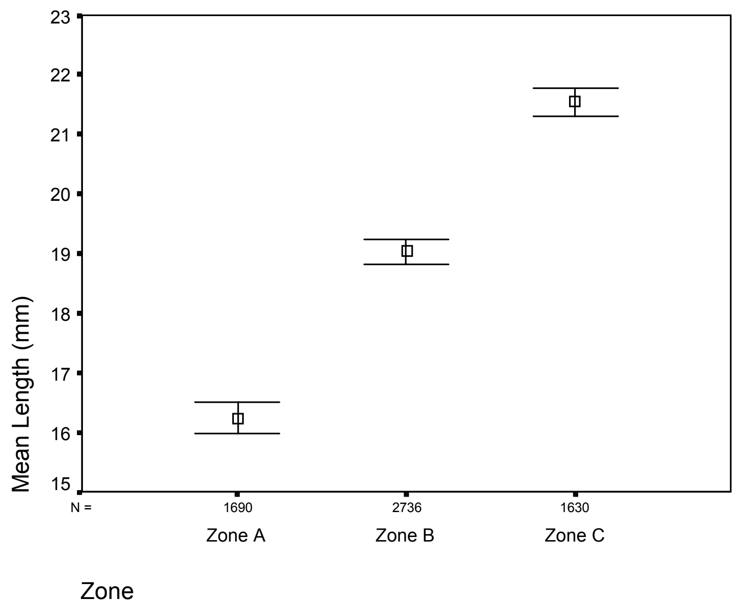


Figure 13. Relationship between shell height and zone in *L. littorea*. Error bars represent the 95% confidence interval.

3.3.4 Length frequency histograms

Length frequency distributions for 47 measured sites were plotted (Figure 14) in order to determine time of recruitment and to identify different cohorts as indicated by discrete peaks on the histogram. The mean shell height varies considerably from shore to shore, ranging from 13.0mm at Doulus Bay, County Kerry to 28.6mm at Burtonpoint County Donegal. Reports in the literature for mature shell height in *L. littorea* range from 10.6mm to 52.8mm (Reid, 1996). The largest speciman of *L. littorea* measured in this study was 37.0mm in shell height. It was found at Netherton, County Wexford.

In Bullens Bay, where seasonal variation in shell size was observed over a three year period, the mean shell length recorded was 18.3mm ± 6.2. The largest shell size attained in Bullens Bay, measured as a maximum length, was 34.1mm. The length frequency distributions for Bullens Bay varied according to the time of year the sites were surveyed. The population structure of *L. littorea* from November 1998 to August 2000 is shown in Figure 15. The population was generally bimodal during this period.

Figure 14. Length/frequency histograms from shores of varying exposure based on the modified Lewis scale. Graphs are presented in order of exposure, beginning with exposure 2 and ending with exposure 5. Site codes relate to the county where the survey was conducted , e.g. DL09 is site no. 9 in Donegal. (SO- Sligo, MO- Mayo, CE-Clare, K- Kerry, C- Cork, WD- Waterford, WX- Wexford, DN- Dublin, LH- Louth)

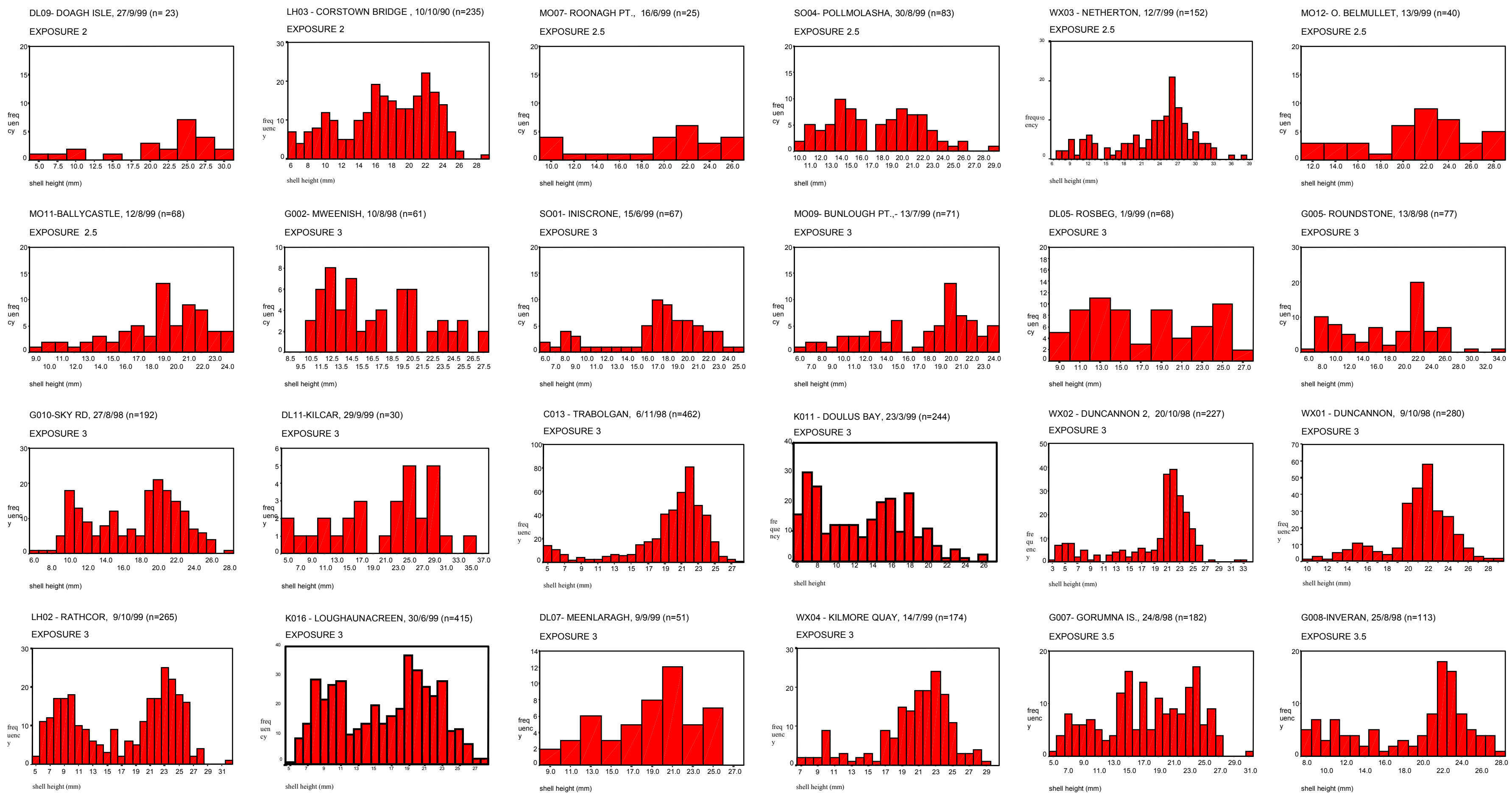
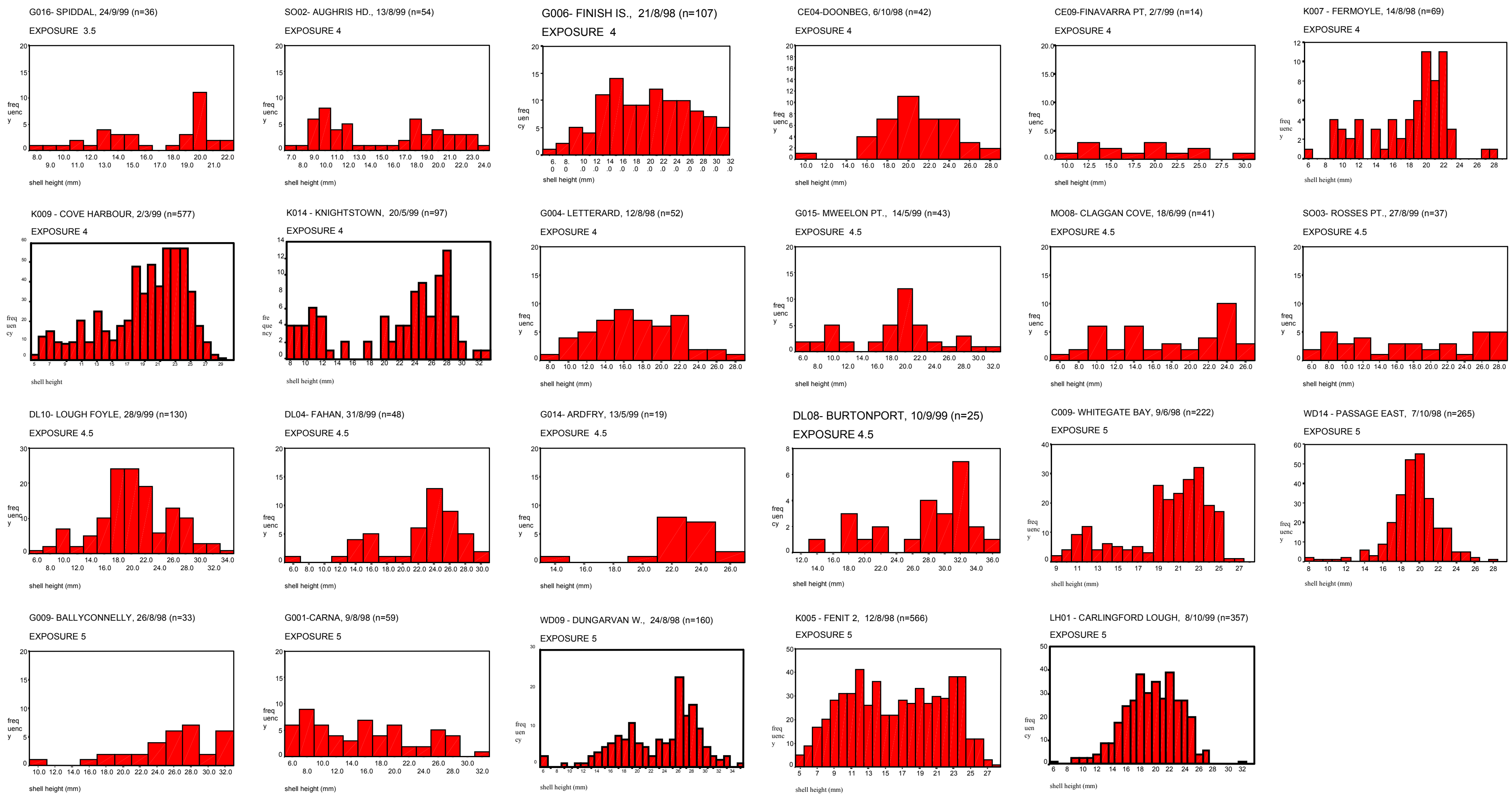


Figure 14 contd'. Length/frequency histograms from shores of varying exposure based on the modified Lewis scale. Graphs are presented in order of exposure, beginning with exposure 2 and ending with exposure 5. Site codes relate to the county where the survey was conducted , e.g. DL09 is site no. 9 in Donegal. (SO- Sligo, MO- Mayo, CE- Clare, K- Kerry, C- Cork, WD- Waterford, WX- Wexford, DN- Dublin, LH- Louth)



BULLENS BAY DATA

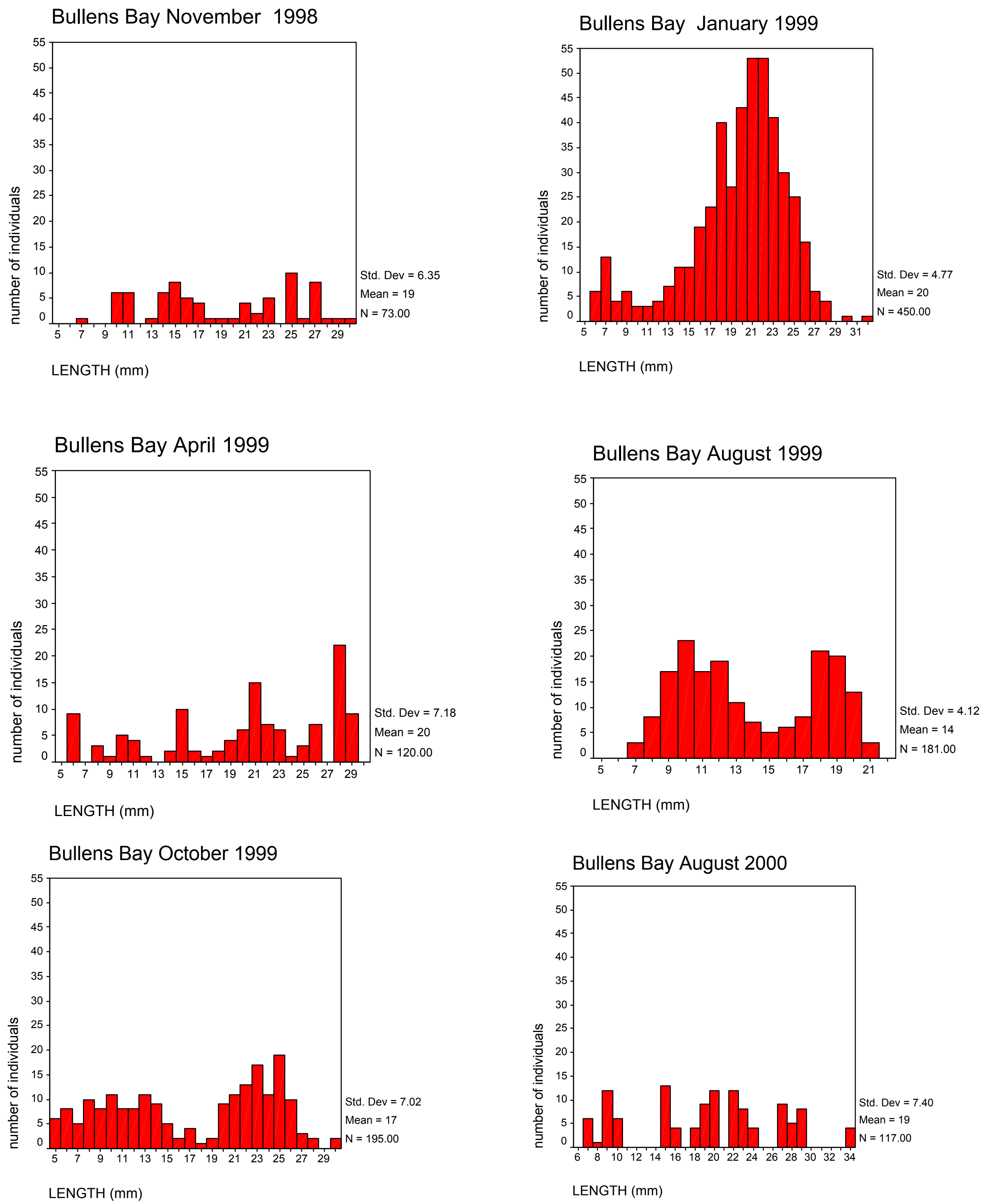


Figure 15. Length frequency distribution graphs of measurements of *L. littorea* taken from one site at Bullens Bay, County Cork. Data were collected over a three year period. Bullens Bay is a sheltered site.

3.4 Discussion

3.4.1 Abundance and distribution of L.littorea

There was a noticeable trend in periwinkle densities between the east and the west coasts, with the lowest densities consistently occurring on the west coast. It is possible that this trend is a consequence of the varying geology around the coast, which gives rise to different types of substratum. The lowest densities of *L. littorea* on harvestable shores were observed to occur around Galway Bay. The sheltered granite shores of Galway afford few crevices and are likely to provide a less suitable habitat for large numbers of *L. littorea.* Some of the highest densities of periwinkles were recorded along the eastern shoreline of County Cork and County Waterford (e.g. 196 per m^2 Whiting Bay, 182 per m^2 Ardmore Strand and 180 per m^2 Clonea Strand). Much of this inter-tidal area is composed of finely stratified mudrock and shale, which when weathered leads to an abundance of small sheltered crevices, ideal habitats for periwinkles.

L. littorea are reported to congregate in hundreds or thousands in depressions and small gullies, especially where algal debris occurs (Lewis, 1964). A significant relationship was noted between periwinkle densities and gravel as a substrate type. Small gullies in which gravel can aggregate so that the substratum is in fact quite stable, provide ideal settlement conditions for larvae; firstly, by providing a large surface area for settlement, and also by providing protection from desiccation, dislodgement and predation (Atkinson and Newbury, 1984). The presence of gravel offers similar advantages to older animals, in particular as a source of protection from dislodgement and predation.

Williams (1964) found very high densities of *L. littorea* on a moderately exposed shore at Craig-y-Wylfa, Wales. This trend is in accordance with the findings of the present study. Moderately exposed shores supporting large populations of *L.littorea* have been described in other studies (Ballantine, 1916; Graham and Mill, 1992; Hylleberg & Christensen, 1977; Lewis, 1955; Stephenson & Stephenson, 1972).

There is a general trend for the number of periwinkles per unit area to drop as one moves from the upper shore (Zone A), to the lower shore (Zone C). This was found to be the case for example in Bullens Bay, Kilcrohan, Carnivan Bay and Patricks Bay. This is in accordance with the documented research on periwinkle ecology (Crothers, 1992; Williams, 1964). However, there were a number of sites where the density incline appeared to be reversed e.g. Carlingford Lough and Aghabeg. These two shores were the only shores with a classification of 1 (extremely exposed) on the Lewis (1964) scale of exposure. It has been suggested that the degree of wetting on an exposed upper shore allows periwinkles to extend their range upwards (Moore, 1940). Perhaps the opposite is true for an extremely sheltered shore; further studies would have to be undertaken with more sampling locations to conclude this with certainty. In addition, there were a number of sites where the highest density of *L. littorea* occurred in Zone B, the middle shore. This was most notable on the east coast around Wexford, (e.g. Netherton; Crossfintan

Point; Rosslare Harbour), Dublin (e.g. Skerries; Rush), and Louth (e.g. Rathcor; Corstown Bridge; Clogher Head). The coastline on the east coast is generally flat and not as rugged as on the south and southwest coast. As a result, zonation is not as pronounced as it is on rocky, rugged shores. This could be the reason why higher densities of *L. littorea* appear to occur on the middle shore, in particular on the east coast. It was also noted during sampling that periwinkles on exposed shores were largely confined to rockpools, thereby avoiding much of the dessication effect associated with living high on the shore. Food availability may also be a factor in shoreline distribution, as most algae on the sampled exposed coasts were found in rockpools.

Environmental conditions such as temperature and input of freshwater were observed during the surveys. Freshwater inputs were observed at some sites (e.g. North East of Fort Point, Cork), in the form of streams flowing to the sea. However, these did not appear to have any impact on *L. littorea* populations at particular sites, even though an abundance of *Ulva lactua* was often associated with the streams. It is impossible to draw any conclusions from the recordings of temperature that were made, as most of the surveys were done between June and September, with no significant variation in temperature recorded during those months. Seasonal variation in periwinkle densities, observed at Bullens Bay, where samples were collected at different times over a three year period, may be attributed to many factors. These include population dynamics, as well as external factors such as storminess, degree of wetting, variation in collection rates by pickers etc. Temperature is one of many factors that may potentially influence the variation in population densities.

Finally, periwinkles are never uniformly distributed and shorelines are never uniform in nature. The methodology adopted for this study was designed to ameliorate these features; however, it is very difficult to represent an entire shoreline on one visit, in just three 30m belts. In conclusion, it is unlikely that the density of populations of *L. littorea* is determined by a single factor, but rather from a combination of many acting together, to provide optimal conditions where adults can thrive in large numbers, and where optimal settlement may occur and hence maintain a high density. Several factors were examined (exposure, topography of the shore, and algal cover). However, other factors are likely to be involved, which were not taken into consideration, such as the absence or scarity of important competitors (especially limpets); settlement conditions; intraspecific competition for food; intraspecific competition for space; and tidal range and emersion periods. Exposure and substratum of a shore, however, are likely to be amongst the most important factors.

3.4.2 Temporal variation in density at Bullens Bay in County Cork

At Bullens Bay, where temporal variation in density was observed, it appears that lowest densities of periwinkles occur during the winter period. This may be a consequence of natural mortality, or increased harvesting activity, as this shore is intensively picked during the winter. Another possibility for the reduced densities in winter could be a result of a sub-tidal migration. Sub tidal winter migrations may minimise exposure to freezing temperatures at this time of the year (Gendron, 1977). The effect of temperature extremes created by daily tidal immersions would also be minimised due to reduced periods of exposure. It is unlikely that periwinkle harvesting is responsible for the reduced numbers of *L. littorea* on the upper and mid shore regions during the winter period, as picking tends to be concentrated on the lower shore, where the largest periwinkles are to be found. It is possible that settlement of new juveniles (assuming that settlement occurs in early January/February in Bullens Bay) is responsible for the apparent increase in the density of periwinkles observed on the shore in late spring. Gendron (1977) working on a population of *L. littorea* in North America, found that the largest decrease in the density of periwinkles occurred between October and January. A similar pattern of change is apparent in the results from Bullens Bay.

3.4.3 Shell measurements of L. littorea

Intensive over-picking of a shore can have an impact on shell height as many of the larger animals are removed. However, no clear relationship between shell height and over-picking was identified from the data collected from one off site visits in this study. The intensity of the picking effort varies considerably from shore to shore and will often depend on current market prices and the time of year. In addition the mean shell height obtained for a shore does not reflect the number of very large or small periwinkles found in a population. Due to the extended planktotrophic larval stage in *L. littorea*, which leads to a relatively genetically heterogenous population, most observed morphometric variation is considered to be a result of natural selection and/ or the ability to adapt to the surrounding environment (Crothers 1992, Reid 1996).

In an examination of the relationship between shell measurements and exposure, the correlation between shell height and exposure was weak, however, the correlation between shell width and exposure was significant. While it is clear that the periwinkles from the most sheltered shores are larger than those from shores of intermediate exposure, the pattern is not one of consistent increase in size with decreasing exposure. This may be a consequence of small sample size, as measurements were only taken from seven shores with exposures greater than 3 on the Lewis scale of exposure.

L. littorea have been observed to adapt their shell morphometry, particularly their shell shape ratio, in relation to exposure. An increase in the value of the shell shape ratio corresponds to a decrease in aperture height. In *L. littorea* a smaller aperture, more characteristic of sheltered shores, is believed to be an advantage in avoiding predators (such as birds and crabs), which feed more effectively on sheltered shores (Crothers 1985, Robertson 1992). The larger aperture of animals from more exposed coasts is believed to allow for a larger foot and consequently a stronger hold on the substrate; this pattern was shown for other Littorinids by Raffaelli (1982). Crothers, 1992 also suggested a relationship between shell length and exposure. A lower spire reduces drag and hence provides an advantage on exposed shores. Exposure was shown to have a demonstrable effect on relative aperture height with significant correlation between exposure and shell height/aperture height ratio. In this case, an increase in the value of the shell height/ aperture height ratio corresponds to a decrease in aperture height, so a positive correlation points to a reduced aperture height on sheltered shores.

The effects of vertical position (zone) on the shore are quite distinct. Shell height is very strongly correlated with zone i.e. shell height increases down the shore. This agrees with the findings of other authors in studies of the influence of shore height on shell length in *L. littorea* (Vermeji, 1972; Gendron, 1977). The relationship between vertical position (zone) and shell morphology may indicate a seaward migration of older animals, or perhaps it is only on the lower shore that periwinkles achieve the largest sizes. McQuaid (1981) suggests that the greater tenacity of adults allows a gradual downshore migration of growing animals in response to gradients of food availability. This could be explained by the greater availability of food on the lower shore, where algal densities are higher. In addition *L. littorea* are stimulated to feed when immersed by the tide and when damp conditions prevail (Newell, 1958; Moore, 1937; Williams, 1964). Thus, the larger animals found on the lower shore have greater opportunities for feeding due to the regular influence of the tidal cycle on immersion rates.

3.4.4 Population structure of L. littorea

Sites favoured for settlement seem to be shores of moderate exposure (Lewis scale 3-4) with rocky and/or gravel substrates e.g. Rosbeg County Donegal (DL05), Kilcar County Donegal (DL11), Sky Road County Galway (G010), and Mweenish County Galway (G002). Three possible reasons for this pattern are outlined:

1. Sheltered sites are favoured by juvenile periwinkles for settlement purposes;
2. Mortality rate of newly settled juveniles on sheltered shores is considerably greater;
3. Growth rates are less on exposed shores.

While it is likely that growth on more exposed shores is slower, this does not explain the low levels (or absence) of juveniles on very sheltered shores, for example, at Ardfry, County Galway (G014), Ballyconnelly County Galway (G009), and Passage East, County Waterford (WD14). One explanation for this pattern put forward by Crothers (1992), involved what he described as the "whiplash effect" of dense fucoid algae which sweep away newly settled juveniles. Once juveniles survive early settlement, animals grow rapidly and may live for many years. In contrast, on an exposed shore, while conditions for settlement may be favourable, especially on barnacle covered rocks, few individuals survive winter storms (Crothers, 1992).

Large numbers of small periwinkles were observed at the Carna site (G001), however, this site was not as muddy as many sheltered sites and consisted of large areas of gravel and small stones. Seaweed cover is sparse in areas where the substrate is unstable, which would reduce whiplash effect. Water flow was also greater than would be expected due to considerable influx of freshwater and run-off from a tidal lagoon. A site in County

Kerry, Fenit 2 (K002), also does not conform to this pattern, proving that each shore is unique and many environmental parameters may affect settlement.

The shell height of cohorts will vary according to the time of year the site was surveyed and the time of settlement at the site. Spawning times are known to vary geographically; in addition, *L. littorea* has an extended spawning time (Fish, 1972). These factors may confuse the interpretation and comparison of length frequency histograms. However, it is usually possible to determine size/age classes from within an individual shore. Many of the histograms from exposed or semi-exposed shores show evidence of 2-3 size classes e.g. Rosbeg, County Donegal (DL05), Meenlaragh, County Donegal (DL07), Loughaunacreen, County Kerry (K016) and Corstown Bridge, County Louth (LH03). The smallest size class would, if a spring spawning were to be presumed, represent that year's settlement. It is rarely possible to decipher more than three age-classes, probably a result of a slowing of growth with age and maturity.

In sheltered shores, where there appears to be less recruitment, periwinkles appear to be larger and this is borne out by statistical analysis. In terms of population dynamics, it makes more sense that recruitment is highest where mortality is highest. This may also indicate that sheltered shores, where the largest periwinkles occur, are more susceptible to the effects of over-picking.

3.4.4.1 Population structure of L. littorea at Bullens Bay

In general, the length frequency distribution for the sampled population of *L. littorea* at Bullens Bay appears to be bi-modal. The data for periwinkles measured in November 1998 represent a low number of samples, for periwinkles less than 10mm. The cohort with a modal height of 7mm in January 1999 appears to have reached a shell length of 10mm by August 1999, and a shell length of 15mm by August 2000. Assuming that settlement occurs in late spring (May), the snails with a shell length of 10mm in August 1999 could be up to 15 months old. It could be said that the animals that obtained 14mm in August 2000 were approximately 27 months old. In November 1998, there was a high density of *L. littorea* at a modal height of 15mm. By August 2000, this cohort appears to have achieved a length of 20mm. Thus, it could have taken 21 months to grow from 15mm to 20mm. This would indicate that animals with a shell length of 20mm could be up to 4 years old. Previous studies have shown that a shell length of approximately 8mm is achieved at the end of the initial year of growth, increasing to about 16mm in length by the end of the third year (Williams, 1964; Hughes & Answer, 1982; Crothers, 1992). The findings at Bullens Bay are in keeping with these approximations of growth. However, Moore (1937) suggested faster growth rates in a study on *L. littorea* in Plymouth, for example, *L. littorea* has been shown to grow to 14mm shell length in December of its first year and reach a shell length of over 27mm by its fifth year.

L. littorea shows considerable variation in growth rate for the first four years of its life (Moore, 1937; Williams, 1964). The results from Bullens Bay indicate variable growth rates (approximately 8 months to grow from 0.5mm to 7mm; 7 months to grow from 7mm to 10mm; 12 months to grow from 10mm to 14mm). These figures assume that settlement occurs in early summer (Smith & Newell, 1955; Williams, 1964), and that *L. littorea* settle at a shell height of approximately 0.5mm (Smith & Newell, 1955). They do not take into account possible spurts in growth at productive times of year. A pattern in growth rates of *L.littorea* was observed by Lambert and Farley (1968) and by Gardener and Thomas (1987). The general trend was for growth rates to increase from May to early July, followed by a decrease in growth rates from mid-July to mid-August. Growth rates were observed to increase again in early September, before declining in the winter months. Periods of shell growth are interrupted when conditions are favourable for reproduction (Williams, 1964). Williams (1964) observed active shell growth on a shore in Wales, from July to October, which corresponded with a period when mature animals were fully spent. Growth rates decreased when gonad maturation began again the following November. Fretter and Graham (1960) observed a looser growth cycle, when, on reaching sexual maturity a cessation in growth occurred in correspondence with a period of maximum sexual activity. Maturity is thought to occur 12-18 months after settlement once a shell length of approximately 11mm has been reached (Williams, 1964). However, analysis of specimens collected from a shore in Galway during this study, showed the age of first maturity as approximately 15mm for males, and slightly higher for females; the smallest ripe female had a shell length of 17mm (Unpublished PhD data, Shellfish Research Laboratory, Carna). Taking this into account, it is unlikely that observed variable growth in animals less than 14mm in August 2000 can be attributed to sexual activity. Factors such as temperature, food availability, exposure, predation, competition and salinity also have an impact on growth (Pertraitis, 1982, 1987; Crothers, 1992; Reid, 1996; Robertson, 1992). It is possible that these factors have a greater impact on growth in periwinkles less than 14mm in Bullens Bay. The mean density on the shore was found to be high, approximately 63 periwinkles per m^2. Thus, competition could be an important factor limiting growth of the periwinkles on the shore in Bullens Bay.

There were considerable variations in the numbers of periwinkles >25mm shell length on the shore in Bullens Bay over the sampling period. This pattern could be attributed to harvesting pressure, as the largest periwinkles are the most desirable on the market. For example, in November 1998, a cohort with a modal height of 26mm was identified. By August 1999 no periwinkles >21mm were observed in the samples. However, by October 1999 a peak at a modal height of 25mm re-appeared. It is questionable if this same group grew to the observed shell length of 28mm in August 2000, as growth rate has been shown to decrease rapidly with age. Very little research has been carried out on growth rates in larger animals, although it is known that periwinkles >25mm must be several years old. The largest animal measured from Bullens Bay was 34.1mm in shell length.

A difficulty arises in using a harvested shore, such as Bullens Bay for studying the population structure of *L. littorea* as one of the main factors influencing such population structure will be harvesting itself. Temporal variation in periwinkle harvesting at Bullens Bay leads to difficulty in the interpretation of the impact of this activity, however, it is likely that harvesting has an impact on the population structure of *L. littorea* at this site, and that this impact extends to periwinkles that are greater than 14mm in shell length. In addition, the lack of measurements of periwinkles <5mm shell length meant that variations in recruitment patterns could not be observed. Nevertheless, it has been possible to suggest a model of growth in Bullens Bay.

SECTION 4 - INDUSTRY REVIEW

4.1 Introduction

Littorina littorea is collected in large quantities for human consumption. Collection is usually carried out by part time fishermen and by women (O Sullivan, 1977). Wright (1936) states that in the Blackwater Estuary, Essex, commercial quantities of periwinkles were dredged from sublittoral channels; however, gathering in Ireland is carried out by hand. Periwinkle harvesting is done during spring tides. Periwinkles are easier to harvest during this period as the lower shores, where the largest periwinkles are found, are more accessible. Some picking is done during periods of neap tides, but the quantity harvested is considerably less (T. Tobin, Youghal, pers. comm., 2000). When demand for periwinkles on the continent is high, and when prices are good, there is an increase in the number of people picking, and in the quantity of periwinkles exported. Extra demand for periwinkles at Christmas drives the price up from approximately £1,400 to £2,200/tonne, making Christmas one of the busiest times for periwinkle pickers and wholesalers. Some harvesters only pick at this time of the year, as the higher prices make it more worthwhile, and the extra cash is often needed. There is a subsequent post Christmas lull in the demand for periwinkles; demand increases again around Easter (K. Flannery, Dingle, pers. comm., 2000). Demand for periwinkles in the summer months has increased in recent years attributable to the increased volume of trade experienced in France by restaurants at that time of year.

Traditionally, the price obtained for periwinkles varied throughout the year, in accordance with the demand from foreign markets, (Wright, 1936). Seasonal trends in price still occur today. Price also depends on the size of the periwinkles, and whether they are graded or not. Wholesalers can also have an impact on the price a picker can get. Some wholesalers keep the price artificially high; this ensures the loyalty of the pickers when there is competition amongst wholesalers for stocks, and also encourages pickers to harvest in the run up to Christmas. Generally speaking, a picker could receive as little as 80p per kilo, but this can increase to around £1.50/kg at Christmas time. Wholesale prices are in the region of £2.10/kg for periwinkles less than 13mm, and about £2.50/kg for periwinkles greater than 15mm. Periwinkles are usually exported with other shellfish, and transport costs vary from 12p/kg plus VAT, to 22p/kg plus VAT for groupage.

The market price plays a major role in the number of people picking at any one time (McKay and Fowler, 1997). Market prices were very good in 1999, but they were subsequently affected by the oil tanker (the *Erika*) accident off the Brittany coast in December 1999. There is a demand for Irish periwinkles from French oyster farmers who use them to graze the algae that fouls the oyster bags. As a result, any impact on the French oyster industry, such as an oil spill, has a knock-on effect on the Irish periwinkle market.

There are no regulations in place to control the quantities of periwinkles harvested per year. Periwinkle picking is very much a 'free for all' situation; establishing oneself as a picker requires little more than a bucket. Despite the evident lack of regulatory control, all periwinkles collected in Ireland must meet the end product standards outlined in the European Community Directive on Shellfish Hygiene 91/492/EEC. This requires all shellfish harvesters to maintain a Harvester Book, which should log details of the species gathered, time and location of harvesting, quantity collected and destination of the shellfish. Rigid implementation of the harvesters book system is difficult to ensure in this industry. These regulations also require that wholesalers operate from a registered dispatch centre, which has been allocated a veterinary inspection number. This number is necessary in order to obtain an export licence. It also confirms that the premises has passed the required standard in terms of hygiene. These controls are enforced by the Department of the Marine and Natural Resources.

Historically, the only information on the Irish periwinkle industry has been compiled by the Department of Marine and Natural Resources (DoMNR). Up until now, no effort has been made to examine the periwinkle industry in Ireland as a discrete entity. In this section, an attempt has been made to estimate the true size and nature of the periwinkle industry in Ireland. The research methods and results are presented below.

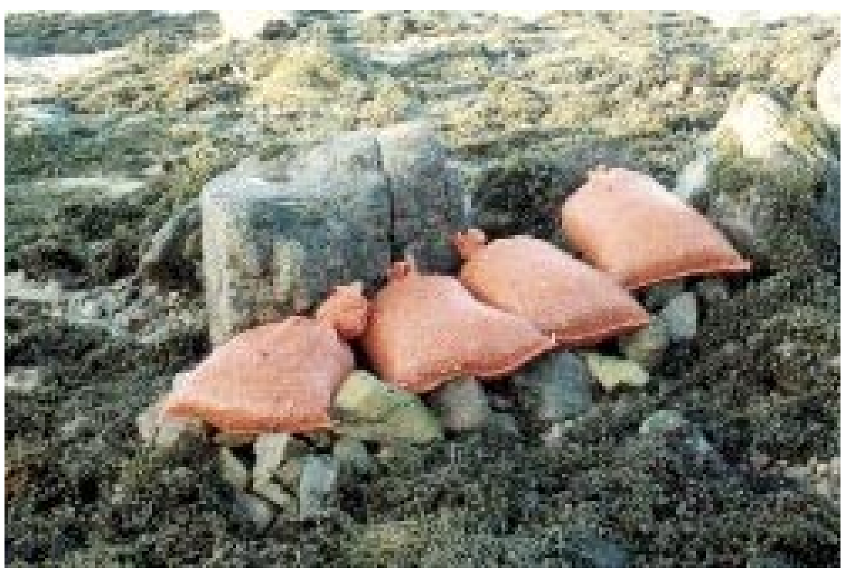


Plate 2. Bags of harvested periwinkles, *Littorina littorea,* awaiting collection from a shore in Galway.

4.2 Research Methods

A confidential questionnaire, directed at periwinkle wholesalers, was designed to obtain information on the periwinkle industry. Twenty-six wholesalers were identified nationally, all of whom responded to the questionnaires, which were distributed between between June 1999 and January 2000. This represents the majority of periwinkle exporters in the country. However, periwinkles are sometimes purchased directly by French and Belgian buyers, which makes it extremely difficult to account for all of the exports. The aim of the questionnaire was to assess the quantity of periwinkles exported from different areas, and to obtain an impression of any changes in the supply of periwinkles from pickers to wholesalers over the last five years. Wholesalers were also asked their opinions about potential management strategies that might contribute to the future sustainability of the industry.

In addition to questionnaires, meetings were organised with as many wholesalers as possible. This was particularly advantageous when visiting a stretch of coastline for the first time, as wholesalers could pinpoint harvested sites for future surveys. Individuals with knowledge of the industry, while not actively partaking in commercial dealings in periwinkles (for example, fisheries officers), were also consulted.

Fisheries landing data was sought from the Department of the Marine and Natural Resources (DoMNR), the responsible authority for maintaining sea fisheries statistics. Periwinkle statistics are collected by Sea Fishery Officers and are then processed by the Department.

Eight seafood restaurants, six in Cork and two in Galway, were contacted by telephone to document the perception of periwinkles as a restaurant food in Ireland, and whether there might be potential to develop the home market further.

4.3 Results

The information obtained from the questionnaires is presented by dividing the coastline into five areas, which represent the main wholesaling areas in the country (Figure 16).

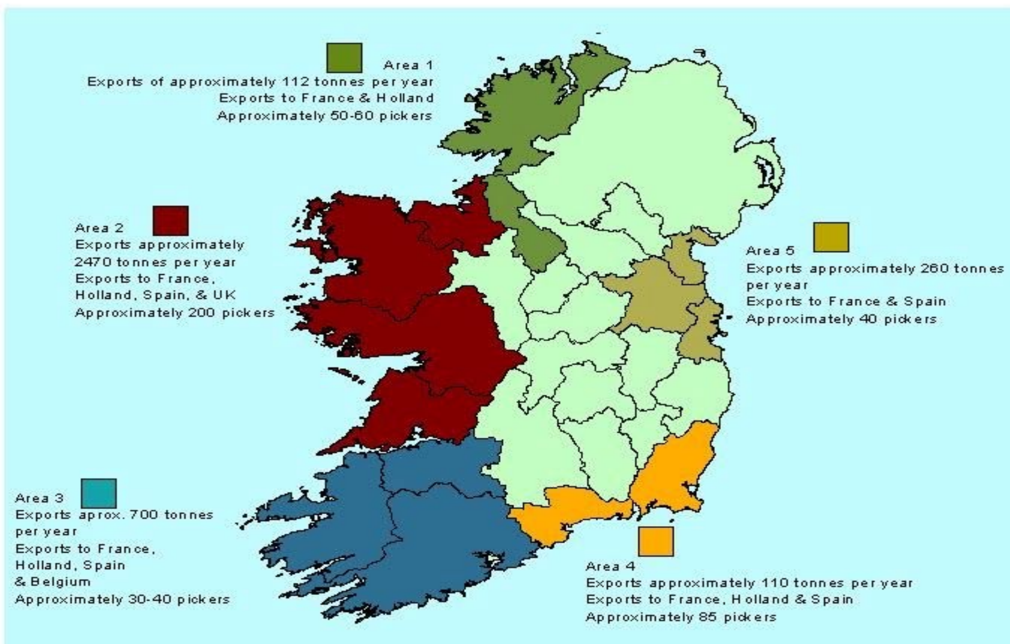


Figure 16. Industry review areas and summary of periwinkle industry activities

4.3.1 Area 1

This coastal area stretches from Rathmullan in County Donegal to Rosses Point in County Sligo. There is one major wholesaler operating from here, as well as two known agents who supply a large percentage of the picked periwinkles to wholesalers in Area 2. Results from questionnaires and interviews indicate that approximately 112 tonnes are exported directly from here per year. The exports are shipped to markets in France and

Holland. Each interviewee claimed that there was a decrease in the quantity of periwinkles being supplied to them; they attributed this to over-picking, picking during the breeding season, and pollution. They also said that regulations need to be put in place to conserve stocks, and mentioned closed seasons and minimum harvesting size as the best options for control. There are an estimated 50 to 60 pickers in Area 1. Periwinkles are exported to France and Holland from this area.

4.3.2 Area 2

This stretch of coastline extends from Rosses Point to Kilrush in County Clare. Seven wholesalers and agents were interviewed in this area, which includes some of the biggest wholesalers operating in the country. These wholesalers export approximately 2,470 tonnes per year. Two individual wholesalers account for over half of this total. All of the wholesalers said that they had experienced a decrease in the quantity of periwinkles they were receiving. While overpicking was cited as the major cause of the decrease by three of the wholesalers and agents, some additional factors, such as a shortage of labour, less picking effort, and pollution were listed as other potential explanations for the decrease in periwinkle supplies. This area contains the largest number of pickers, as there is an extensive area of suitable coastline. Based on wholesaler information, there are an estimated 200 pickers here. Periwinkles from Area 2 are exported to France, Holland, Spain and Britain. A proportion of this harvest is also retained for sale on the domestic market. However, this accounts for less than one percent of the total. Beach front vendors in Kilkee County Clare have operated a seaside business there for over a century. Sales of periwinkles in Ireland are also to be found further up the coast in the seaside town of Lahinch (County Clare) and in County Donegal at Killybegs. All of the interviewees said that regulations should be enforced to help the future sustainability of the industry. They suggested that minimum harvesting size and closed seasons would be the most practical way of achieving this.

4.3.3 Area 3

Area 3 extends from Tarbert in North Kerry to the coastal town of Youghal in East Cork. This area produces a conservative estimate of approximately 700 tonnes per year and there are at least 11 wholesalers operating from here. Periwinkles from this area are exported to France, Holland, Belgium and Spain. All of the wholesalers in this area noticed a decrease in the number of periwinkles made available to them by pickers. They also noticed a decrease in the average size of the periwinkles picked. Over-picking was listed as a major factor in the decline of periwinkle stocks, while less picking effort also featured as a possible cause. In 1998, the North West Kerry Shellfish Co. Ltd., under proposals for the conservation of inshore stocks of shellfish, submitted to the Minister for the Marine and Natural Resources, a proposal that a minimum size should be introduced for periwinkles harvested and that a closed season should also be introduced. No action was taken on behalf of the government at the time on this issue. Several exporters, pickers and people associated with the industry have expressed a genuine concern for the sustainability of the industry in this area. There are approximately 100 people reliant on income derived from periwinkle picking in this part of the country. Estimates vary according to which wholesaler is providing the information, but there is general agreement amongst the wholesalers that the number of pickers is declining. Many attribute this to the fact that fewer young people are involved in the industry, as there are now more attractive sources of employment elsewhere. One set of figures provided by a wholesaler, showed a decrease in the number of harvesters in an area in east Cork from 30-40 pickers ten years ago, to 7-8 full time pickers today.

One of the wholesalers interviewed in Area 3 said that the average size of the periwinkles being supplied to him had *increased* in recent years. On further questioning, he said that in the early 1990s, he used to purchase undersize periwinkles to sell to oyster-farmers in Brittany (mesh size of less than 13mm). These periwinkles were required to graze the algae in oyster bags. The on-grown periwinkles were then sold to the local markets by the oyster farmers. This practice ceased in 1993 when the French oyster production suffered problems with disease. As a result, the market for seed, small and medium periwinkles gradually decreased.

4.3.4 Area 4

This area consists of the coastline from Youghal to Rosslare, and includes the sheltered Dungarvan Bay, where much of the periwinkle picking takes place. Approximately 110 tonnes of periwinkles are exported annually from this area. There are three major wholesalers operating from here, two of whom rely on agents from other parts of the country to supply additional stocks when the demand is high. Shipments are made through the port at Rosslare, and the periwinkles go to France, Spain and Holland. All of the wholesalers in this area stated that the quality of the periwinkles, in terms of size, was good, and that the quantity being supplied to them remained stable. The largest of these wholesalers stopped accepting undersize periwinkles a number of years ago, and he attributes the recent prevalence of very big periwinkles to this practice. Nevertheless, all of these wholesalers said that regulations should be introduced to control the industry nation-wide, and they all favoured closed seasons and minimum sizes as the best methods of control. There are approximately 40 regular pickers from Dungarvan to Passage East in County Waterford, and a further 45 pickers from Arthurstown to Rosslare Harbour in Wexford. Some of this harvesting is reportedly done by ‘New Age Travellers’ who have been harvesting periwinkles in the region in recent years. Locals have commented on seeing groups of up to ten 'New Age Travellers' work a stretch of shore for the duration of a spring tide, and then move on to the next stretch of coastline. Several of the locals that were interviewed in the area were worried about the impacts of this intense harvesting method on the local periwinkle stocks.

4.3.5 Area 5

The coastline north of Rosslare to Dublin is largely made up of sandy, muddy foreshores, so periwinkle harvesting does not occur on a commercial scale in this region. Consequently, Area 5 extends from the North Dublin coast as far as Carlingford Lough in County Louth. There is one wholesaler from the Republic operating in this area. He also collects periwinkles from north of the border. He stated that fewer people are picking periwinkles in the region now than before, and that over-picking is not a problem. His volume of trade has increased in the past few years due to other wholesalers relinquishing their business. There are about 20 pickers between Clogher Head and Carlingford Lough that pick all year round. This number increases to approximately 30-35 people in the winter season (November to March). There are a similar number of harvesters that work the coast between Clogher Head and Rush. These are all local people; up to 90% of the picking is done by men.

4.3.6 General results

During meetings with the wholesalers, it became apparent that many would be interested in exploring the potential for on-growing. On-growing would involve taking seed and small periwinkles and maintaining them in an aquaculture system until they were of commercial size.

There is little, if any, post harvest processing. Some wholesalers provide special 10kg collection bags for the pickers to fill. These bags are collected, given quick inspection for general size of the periwinkles, and packed for immediate export. In the country of import, the periwinkles are usually separated into small 5kg bags. These are then placed into one large 40kg or 50kg bag, and sold to shops and restaurants. The 5kg bags are convenient for restaurants with large turnovers, as the periwinkles can be 'boiled in the bag'. Alternatively, the periwinkles are packaged loosely into 5kg polystyrene boxes. These boxes can be stored in the fridge, and the required quantity of periwinkles can be removed and cooked as desired. The periwinkles will remain fresh for several weeks in the fridge.

Ten of the 24 wholesalers said that they grade the periwinkles prior to export. The larger periwinkles command a higher price, making the process worthwhile. Grading is achieved by riddling the periwinkles using a bar or mesh riddle. The bar or mesh spacings vary in size and sort the periwinkles into undersized (to be discarded), medium, large, or jumbo. Most wholesalers classify a periwinkle passing through a mesh size of >15mm as being large. Wholesalers may also have to discard periwinkles that are covered in barnacles, as these are unmarketable. Periwinkles that are not graded in this country are usually graded by the importer on their arrival at their country of destination.

A further value adding technique, practiced by four of the wholesalers, involves allowing the periwinkles to crawl up vertical sheets of Perspex (a practice known as 'crawling'). Using this method, weak and dead periwinkles can be identified and removed prior to packaging. Buyers will pay more for this higher quality product.

One individual wholesaler investigated cooking and freezing the periwinkles so that they could be vacuum-packed and supplied to the market year round. He tried introducing the product at several trade fairs in France, but quickly realised that there was little demand.

Plate 3. Ungraded periwinkles photographed at a wholesalers premises in County Mayo.

Plate 4. A periwinkle grading machine.

4.3.7 Analysis of official fishery statistics

Annual reported catches of periwinkles can be seen from the sea fish landings by species, collated by the Department of Marine and Natural Resources. These figures are based on information provided by the wholesalers to the DoMNR's Sea Fisheries Officers. The wholesalers are under no statutory obligation to do this, thus the reliability of the data can often depend on the level of trust built up between the two groups.

Annual reported catches of periwinkles since 1973 are given in Figure 17. This data indicates that an average of about 2,370 tonnes per year were landed in the 1970s, with a peak of 2,995 tonnes in 1975. There was a decrease in the catch during the 1980s when the average figure was 1,604 tonnes per year, and landings fell to 1,198 tonnes in 1981. Periwinkle landings have gradually risen again since then, and in the most recent years for which data are available, catches have remained higher than the 1970s average. This is in direct contrast to the information derived from the questionnaires, which indicates that wholesalers have experienced a general decline in the quantity of stocks handled by them since 1995.

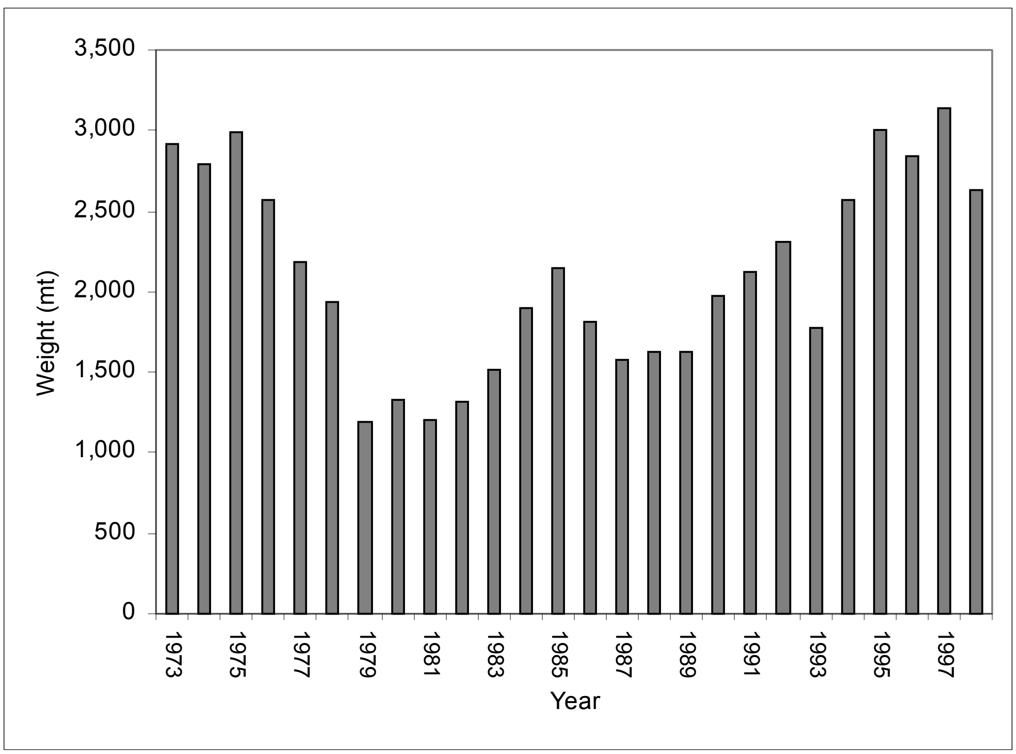


Figure 17. Catches of periwinkles in Ireland 1973 to 1998.
Source: Department of Marine and Natural Resources.

4.3.8 Feedback from seafood chefs

Three out of the eight restaurants contacted had periwinkles on their menu at one time or another. Two of these restaurants stopped serving periwinkles, due to the lack of demand. The general opinion of all of the chefs interviewed, was that periwinkles are tedious to eat and people are not practised in extracting them from the shell. There are also limitations on how they can be cooked and presented. One chef thought that the modern trend for convenience foods had made people reluctant to put effort into extracting the snail from the shell. On the other hand, the chef of a French seafood restaurant thought that this aspect of the food source was one of the attractions.

In general older people, in the 50 plus age bracket, eat periwinkles; traditionally in Ireland periwinkles were boiled in milk with onions. Irish people living in the coastal counties are more inclined to eat periwinkles than are their inland counterparts.

Three of the chefs stated lack of familiarity with the supply chain as a reason for not using periwinkles. Fear of contamination was also stated by two of the chefs as a reason for not using them.

When asked if there would be any potential for increasing the quantity of periwinkles being used in Irish restaurants, the replies were positive from six of the eight chefs questioned. The general opinion was that Irish people were experimenting more with the types of food they eat. The increasing popularity of mussels and oysters over the last 10 years was given as an example of this change. It was observed that if periwinkles were well marketed, there could be a change in attitude towards eating periwinkles, either as bar food, or as part of a seafood platter.

The main potential for selling more periwinkles on the Irish market comes from the increasing numbers of tourists visiting Ireland each year, especially the French and the English. Five of the chefs said that they would consider putting periwinkles on their menus (if they could find suppliers), during the tourist season; one of the chefs, who already does so, said that periwinkles were popular with his customers.

4.4 Discussion

Many of the results presented in this section of the report are based on the opinions of wholesalers. Due to the difficulty in identifying harvesters willing to discuss their involvement in the industry, the wholesalers themselves were also reluctant to provide detailed information on the sources of their supplies, to protect those individuals who may also claim unemployment and other social welfare benefits. As a result, the findings presented here reflect the difficulty in obtaining a clear picture of what is happening in this 'black economy' type industry.

In other ways, the wholesalers were very forthcoming with regard to how they operated their businesses. However, many of the export figures provided are thought to be an underestimate of the true quantity of periwinkles landed. The figure of approximately 3,650 tonnes exported per annum, obtained from the results of the questionnaires, is likely to be a conservative estimate of the true quantity of periwinkles actually harvested. This may be due to a reluctance to reveal figures for periwinkles that are exported unreported. In addition to this, there are cases around the coast, where pickers have built up contacts with importers in Belgium and France, and export their harvest directly. It is also difficult to estimate the quantity of periwinkles taken out of the country by French buyers who bypass the Irish wholesalers. As a result, it would be reasonable to estimate that the true quantity of periwinkles exported from Ireland may be closer to over 4,000 tonnes per year. Using these figures and current market prices, it is estimated that in excess of £7 million worth of periwinkles are exported from Ireland annually.

There appear to be approximately 500 part-time pickers employed by the industry, although this figure fluctuates depending on the time of year. While this is thought to be a fairly accurate reflection of the current situation, the number of pickers is very much dependant on the economic climate of the day and on the market price for periwinkles abroad.

Further research into the feasibility of **on-growing** could have an impact on the future of the industry. The main aim of this process would be to maximise growth rates so that the periwinkles would be marketable within a profitable time period. On-growing has never been tested on a commercial basis here in Ireland, although research trials conducted in Bantry Bay (Griffiths, 1996) and in Scotland (Cashmore and Burton, 1998) both concluded that benefits may be gained from this type of operation. Development of an artificial diet is something to consider for any large-scale aquaculture activity. An artificial pellet was tested in the Bantry Bay on-growing trials, but it was concluded that several changes would have to be made before this diet would be suitable for periwinkle culture (Griffiths, 1996). Observed problems with the diet included leaching, and lack of palatability. For small scale on-growing of periwinkles, costs would have to be kept to a minimum to ensure profitability of operations. Periwinkles are a low value species in comparison to some other farmed shellfish (such as oysters and abalone). William Connolly's Redmills Ltd. is currently developing Abalone diets, but these will market at £500 - £600 per tonne. For this reason, it might be better to feed the periwinkles on a natural diet of seaweed gathered from the shore. The development of aquaculture facilities suitable for intensive rearing also requires consideration. Such facilities may include a pump-ashore system where environmental parameters could be manipulated to ensure optimal feeding and growth rates. More work needs to be carried out to determine factors such as seasonal changes in growth, the benefits of providing supplementary feed, and the effects of parasitism.

Polyculture is another option for on-growing small periwinkles. This involves growing the periwinkles to a marketable size with another cultivated species. This practice is commonly used by French oyster farmers. The advantage of this procedure is that the periwinkles are very effective at keeping the oyster bags clean of fouling algae. In France, many oysters are grown in intertidal ponds, or parcs, which are ideal for confining the periwinkles with the oysters. Although parcs are not used in Ireland, one oyster farmer in Dungarvan successfully incorporates periwinkles in with his oyster bags as a method of biological control of fouling organisms. Surprisingly, it is not common practice among other oyster growers (R. Harty, pers. comm., 1999).

Post harvest processing of the periwinkles could also be suggested as an area for future focus. The current practice of packaging the periwinkles in 10kg bags keeps the costs down, however it does not ensure a quality product for the buyer. One exporter practising this technique has had non-payment for goods due to the large proportion of undersized periwinkles in some bags. Some pickers have also been known to add weight to the bag by adding stones to the middle. Despite this, many wholesalers believe that minimal handling is the most economically viable strategy. However, there seems to be little room for development in the area of post harvest processing; the greater majority of periwinkles are consumed fresh, either as an appetiser or as a minor part of a seafood platter. Potential seems to exist for selling more periwinkles to Irish restaurants, particularly during the tourist season. Picking during the summer to provide for the home market is unlikely to have any major impact on periwinkle stocks, as the potential size of the market is small.

Grading. As a large number of periwinkles are exported without being graded, it must be assumed that many undersize periwinkles end up in the market place, or that the importers dump them. This trade in undersize periwinkles is of particular importance at a time when so many of the wholesalers have expressed concerns about the resource. On the other hand, each of the wholesalers that employ sorting techniques said that they either return the undersize periwinkles to the shore, or make use of them in some other way. For example, one wholesaler relays them in oyster-bags where they graze the fouling algae from the trestles. Another wholesaler in Kerry uses them to clean his lobster tanks as the periwinkles feed on fouling macro and microalgae. While the return of undersized periwinkles to the shore must be welcomed, its unclear how well the animals recover. However, they obviously fare better than those periwinkles that (as has been suggested) are buried to prevent harvesters from re-picking them.

A number of wholesalers blamed **pollution** for a reduction in periwinkle stocks in certain coastal areas. It is known that *L. littorea* are affected by TBT based antifoulants, which were commonly used on vessels, primarily on leisure craft, until a partial ban was introduced in Ireland in 1997. A study in the UK, on *L. littorea* populations in the estuary of the river Crouch (Essex), showed that the numbers of *L. littorea* eggs and veliger larvae progressively increased following the ban on TBT-based anti-foulings on small boats by the UK government in 1987 (Matthiessen *et al*, 1995). This suggests that TBT may have impaired periwinkle reproduction and/or survival of the eggs and larvae. Another effect of TBT on *L. littorea*, termed imposex, causes formation of male sexual characteristics in females. The effects of imposex on periwinkles in Cork Harbour were studied by Casey and Burnell (1998). Imposex is not fatal and affected populations do not exhibit a male dominated population structure (Baur *et al*., 1995). Also, due to dispersal during the pelagic larval stage of *L. littorea,* populations do not necessarily become extinct as a result of imposex. The majority of harvested shores are located away from harbour areas where TBT might still be present in the sediment, making it unlikely that TBT plays a major role in the availability of the resource at present. However, it may have had a more significant role on the impact of periwinkle populations prior to the introduction of the ban. The other major pollution threat to populations of *L. littorea* is from oil spills; however, these usually have a localised impact, and there has not been a significant spill in Irish coastal waters in recent years.

The official landing statistics from the Department of the Marine and Natural Resources show that there has been a steady rise in the number of periwinkles landed throughout the 1990s (Figure 17). This can be misleading when presented out of context. It is unlikely that this rise is due to increased picking effort, but to a combination of other factors. The introduction of EC Directive 492, which defines end product standards for shellfish, led to improved accountability within the industry. This has had a substantial impact on landing figures since 1991. In addition, the DoCMNR has increased the number of sea fishery officers, so that more accurate information has been collected in recent years. Furthermore, landing figures for the early 1970s (when landing data would have been much more difficult to obtain) are roughly the same as figures for the late 1990s. The figures from the 1970s are likely to be an underestimate; if this is the case, this supports the conclusion that picking effort may be in decline.

Finally, the **overexploitation** of the resource in some locations has been outlined by the wholesalers, but at the same time many of them have noticed a decrease in the number of periwinkles made available to them by pickers. Part of this could be attributed to a reduction in the number of people becoming involved in harvesting. The age profile of harvesters indicates that a shortage of pickers may become a problem in the near future (Section 5). Only 18.5% of pickers interviewed were under the age of 40. Young people perceive periwinkle picking as intensive work, with very little financial return for the effort involved (Section 5).

Based on the feedback from wholesalers, it appears that localised over-picking does occur. The action taken by the North West Kerry Shellfish Co. Ltd. in submitting a proposal for conservation to the Minister for the Marine reflects the level of concern about over-picking in that area. Harvested shores are characterised by easy access, both to the site and to the bottom of the shore. As a result, intensive collecting tends to occur in these areas. This can reduce the overall numbers and size of animals in a population. However, in the absence of a comparable study, it is difficult to determine whether this is a large-scale problem. In addition, *L. littorea* is less vulnerable to the long term effects of over-exploitation than many other species due to its very long planktonic stage and its consequent ability to disperse and re-seed in over-picked areas. As a result, it appears that the major threat to the future of the industry may not be from over-picking, but from the decline in the number of people engaged in harvesting. Section 5 shows that there has been a decline in the number of people involved in picking periwinkles in recent years. The current strong economy in Ireland offers people of all ages a wider range of job opportunities than ever before, and entices them to abandon traditional sources of income. It could be said that the current shortage of periwinkle pickers will provide periwinkle stocks with the opportunity to regenerate themselves, and that it is perhaps the survival of the *periwinkle picker* over the *periwinkles themselves* that we must consider in the future. This reduces the immediate need for regulations to be implemented and should be taken into account before a management strategy is considered.

Regulations to ensure the sustainable development of the periwinkle resource would be welcomed by those who are worried about the conservation of periwinkle stocks. Several exporters, pickers and people associated with the industry have expressed a genuine concern for the sustainability of the periwinkle industry, and were very anxious that regulations are put into place in the near future. A closed season and a minimum harvesting size were the most widely supported regulations presented to harvesters and wholesalers alike.

Closed season. It appears that the motivation behind some of the support for a summer-closed season may be for reasons other than concern for the species. One of the main advantages of a closed season is that it would be easy to enforce. It seems many wholesalers would rather not handle periwinkles during the summer months, when prices are low and periwinkles are difficult to keep. One of the main reasons for continuing to sell periwinkles at this time of year is to maintain foreign customers who might acquire a different wholesaler or agent (perhaps from Scotland) if supplies were not forthcoming. Among pickers, the support for a closed season stems from the fact that few people pick during the summer anyway. A closed season at this time of year would suit those pickers who work on fishing boats or on farms during the summer. As a result, a closed season during the summer, when harvesting is at its lowest, makes little sense. The proposed timing however, makes little biological sense as *L. littorea* appears to spawn in the late winter and spring, and a summer closed season would not protect the animal during this time.

A closed season spanning the months of January to possibly April would best protect spawning periwinkles (pending conclusive research that this is the spawning season for most Irish populations). However, it is unlikely that pickers and wholesalers would support a closed season at any time of the year other than during the summertime. A closed season outside of the summer period could result in a serious loss of income for pickers and wholesalers, due to the closure of the fishery at a time when prices for periwinkles are likely to be high.

Minimum harvesting size. One of the classic signs of imminent problems for a fishery is the increase in sub market size individuals in the catch. The demand for undersize periwinkles by French oyster farmers undoubtedly had a negative impact on Irish periwinkles stocks on certain shores. However, many tonnes of periwinkles continue to be wasted every year because the size of the periwinkles gathered by the pickers is unacceptable for the market. Grading eliminates much of this waste, but it is likely that a large number of periwinkles are dumped, rather than returned to the shore.

The main advantage of the introduction of a minimum landing size therefore would be to force pickers to avoid shores where a large proportion of sub market size periwinkles occur. The majority of the wholesalers questioned suggested 13mm (shell height) as the minimum landed size that should be introduced. This corresponds with the smallest sized periwinkle that would be acceptable on the general market, but fails to take age/size of maturity into consideration. It must be noted that in Galway Bay at least, periwinkles do not mature until they are 15-17mm shell height, (Unpublished work, Shellfish Research Laboratory, Carna), which means that the minimum size advocated by the wholesalers might not protect the species as desired.

The introduction of a minimum landing size would be more difficult to enforce than closed seasons, as a number of wholesalers export periwinkles without grading them. Ideally, the pickers should be held accountable for any sub market size animals in a catch. However, due to the difficulty of identifying pickers, the wholesalers would have to be made responsible for failure to comply with this regulation. The enforcement of this regulation would mean that small exporters would have to buy grading equipment which, possibly, they could not afford. It would also be impossible to ensure that the graded, undersized periwinkles are returned to the shore to allow them to grow to a marketable size.

SECTION 5 -SOCIO-ECONOMIC IMPACTS OF THE IRISH PERIWINKLE INDUSTRY

5.1 Introduction

The aim of the socio-economic study was to evaluate the impact of the Irish periwinkle industry on coastal communities. This section gives an overview of the socio-economic issues derived from the study. These are closely linked with the nature of the periwinkle industry, as outlined in Section 4.

5.2 Research Methods

5.2.1 Questionnaires

A questionnaire was developed to collect information about the socio-economic aspect of the periwinkle industry. Originally, it was intended that the harvesters' questionnaire would be filled out by the harvester in the presence of the picker. However, it became evident that pickers were slightly intimidated by this, thus, a more informal approach was adopted, where questionnaires were filled out after a meeting with a picker. The age, occupation, and gender of the picker was recorded, together with their opinions on prospective regulations and the state of the industry.

5.3 Results

Fifty-four harvesters were consulted during the course of sampling. Of these, 81% were male and only 7.5% were not local to the area. The age profile showed that only 18.5% of pickers were under the age of 40. Most of the pickers interviewed relied on farming/fishing for their main source of income (60% from farming /fishing background: 25% farming and 35% fishing). While picking is almost exclusively used as an income supplement, at least one picker encountered in County Cork makes a reasonable living out of picking alone. There appears to be a real culture of periwinkle picking (often extending back through several generations) as an income supplement in small fishing/farming communities such as Carna, County Galway, and Kilkee, County Clare.

A few pickers took the fishery for granted commenting that "the periwinkles would always be there". However, there was widespread belief that there was a decline in periwinkle numbers in the recent years; many pickers (39%) suggested that this may be a consequence of overpicking; other pickers (15%) suggested that summer picking was the primary cause of decline.

It was impossible to ascertain the precise income of the interviewees. In some instances pickers were so reluctant to talk that even introducing such a question would have made the individual suspicious and unlikely to answer further questions. In many cases, other pertinent questions could not be asked. However, it would be reasonable to assume that most of those interviewed were on a comparatively low income. Many wholesalers and others who have knowledge of the industry claim that pickers rely heavily on social welfare payments, and that this would account for some of their unwillingness to be interviewed.

5.4 Discussion

The industry on the island of Inis Meain, County Galway, (one of the Aran Islands), has been studied by Evelyn Moylan and Paul Cashburn of Taighde Mara Teo. There are 16 harvesters on the island; eight pickers are seasonal workers and only pick in winter when demand is greatest. One interesting demographic to emerge was that most pickers were single men; only two of the 16 pickers were married. It is believed that the industry is worth around £17, 000 per annum to the islanders.

At one point, attempts were made to develop the industry on the island, it was initially hoped to conduct on-growing experiments and to develop a value added brine-pickled product. These projects were aimed at getting local women involved in natural resource based employment. The intended target market was the summer tourist trade. However, those involved became embroiled in arguments over foreshore rights (where certain pickers believed themselves to have the right to pick a certain area, and only that area). The pickers lack of co-operation eventually proved to be an insurmountable obstacle. The periwinkle population on Inis Meain is thought to be heavily overpicked. The area with exploitable quantities of periwinkles is very small and pickers have complained that "Jumbo" sized animals have disappeared. However, there appears to be little understanding that this has, most likely, resulted as a consequence of overpicking (Moylan, E., pers.comm. 1999).

It is of interest to compare the current socio-economics of the industry with those of the periwinkle industry in the early 1900s. The scope and dynamics of the industry were outlined in a study by Browne (1903) and this report provides evidence for a significant decline in the dependence on the fishery in the last 100 years. Browne's report states that around 300 to 400 people were involved in the industry in the early 1900s in the Belmullet (County Mayo) area alone; in 1998 a picker interviewed claimed that only two to three individuals now pick regularly in the area.

Many interviewed said that young people perceived periwinkle picking as being hard work for little return and that well paid work was now easier to come by. The age profile of harvesters may reflect the increasing age profile of many rural areas. Fewer young people now remain in traditional occupations such as fishing and farming (where quotas and regulation have made earning a living increasingly difficult) rather heading for more profitable work in towns and cities. The increase in third level attendance over the last twenty years may also have had an effect. Research carried out by the ERSI in 1999 showed that 6,000 people left all the Gaeltacht areas (traditionally areas with a high level of harvesting) in the past five years, 40% of whom were under 25 years of age. 50% percent of those leaving had third level qualifications (cited in Ireland on Sunday 16/1/00). This decline in the numbers picking regularly was mentioned by several wholesalers. Many complained that pickers were simply dying out and the age profile of pickers seems to confirm that this is the case. During the Christmas season, at least one wholesaler keeps the price paid to the harvesters artificially high in order to provide an incentive to pick and hence ensure continuity of supply. Other notable changes since the turn of the century include a shift from the mainland UK (particularly London) to European markets as the focus for export.

The recent high price of periwinkles has made them more attractive to pickers, thereby increasing the pressure on this fishery. The average price per tonne has risen steadily in the last few years;- from £569 in 1991 to £788 in 1996 (Central Statistics Office, 1999). This high price has removed some of the stigma attached to periwinkle harvesting that has existed in the past when periwinkle picking was considered a menial occupation.

SECTION 6 - CONCLUSIONS AND RECOMMENDATIONS

6.1 Summary and Conclusions

6.1.1 Resource Assessment

- The survey of harvestable shores showed geographic variation in the abundance of *L. littorea*. These variations may be a consequence of the varying geology around the coast. The highest densities of *L. littorea* per area on harvestable shores, as indicated by the present study, occur along the coasts of County Cork (east) and Waterford. Much of the inter-tidal area along the eastern shoreline of County Cork and County Waterford is composed of finely stratified mud rock/shale, which, when weathered leads to an abundance of small sheltered crevices, ideal for periwinkles.

- The lowest densities of *L. littorea* on harvestable shores, as recorded by the survey, were shown to occur around Galway Bay. The sheltered granite shores of Galway afford few crevices and are likely to provide a less suitable habitat for large numbers of *L. littorea.*

- The highest densities of periwinkles, occur on semi-exposed shores, (as recorded on shores such as Knockadoon and Ardnahinch, East Cork), with lower densities at both very sheltered (e.g. Ardfry and Mweelon Point, County Galway) and very exposed sites, (e.g. Fanore, County Clare).

- A large variance in population densities of *L. littorea* existed at the different survey sites. It is unlikely that the density of a population is determined by a single factor, but rather from a combination of many factors acting together. Migration, recruitment and harvesting have an impact on periwinkle densities on a shore. Exposure and substratum of a shore, are also likely to have considerable impact on population densities.

- Exposure has an effect on zonation on the shore. Periwinkles on exposed coasts were found higher on the shore than those on sheltered shores.

- It was found that the highest densities of *L. littorea* tend to occur on moderately exposed shores, 2-4 on the Lewis (1964) scale of exposure.

- There was a significant relationship between gravel as a substrate type and periwinkle densities; gravel can provide significant protection from dislodgement and predation.

- The largest periwinkles were found on the most sheltered shores; however, no consistent pattern of increase in size with decreasing exposure was detected.

- Aperture height is smaller in animals from sheltered shores, this is in accordance with the findings of other authors.

- There is a strong correlation between periwinkle size and position on the shore. Most large animals being found at the lowest inter-tidal levels.

- Aperture size of larger individuals is generally relatively smaller than that of small animals. This may be due to the fact that most large animals were found on sheltered shores, or that the selection pressure for a large foot is not as great for large/ lower shore animals.

- Minimum densities of *L. littorea* occurred during the winter period at Bullens Bay, which may be a result of natural mortality, harvesting pressures or sub tidal migration. Further observations could be carried out in this area to investigate migration patterns.

- It appears that localised over-harvesting of periwinkles occurs in certain coastal areas; however, with a lack of historic scientific data, it is difficult to determine whether this is a large scale problem. The resource assessment carried out for this project provides a bench-mark to which subsequent studies can be compared for evidence of overpicking.

- Harvesting almost certainly has an impact on population structures in Bullens Bay, and that this impact extends to periwinkles that are greater than 14mm in shell length.

6.1.2 The Irish periwinkle industry

- Results from questionnaires indicate that approximately 3,651 tonnes of periwinkles are exported from Ireland per annum. However, it would be reasonable to estimate that the true quantity of periwinkles exported is higher, due to the black market nature of the industry. Using this figure and current market prices, it is estimated that in excess of £7 million (approx €8.9 million) worth of periwinkles are exported from Ireland annually.

- There were approximately 500 part-time pickers working in the industry in the study area in 1998/1999. This figure is based on estimates provided by the wholesalers. The number of people involved in periwinkle picking at any one time is very much dependent on the economic climate of the day and the market price for periwinkles abroad.

- The age profile of pickers indicates that a shortage of harvesters may become a problem in the near future. Only 18.5% of pickers met with on the shore were under the age of 40.

- Young people perceive periwinkle picking as difficult, labour intensive work, with very little financial return for the effort involved. Within the current economic climate, alternative, better paid work is easier to come by.

- Sixty percent of the pickers interviewed came from a fishing (35%) or farming (25%) background.

6.1.3 Management Options

- Several exporters, pickers and people associated with the industry have expressed genuine concern for the sustainability of the periwinkle industry. They were very anxious that the findings of this project would result in regulations being put into place in the near future. However, there is no conclusive evidence to suggest that stocks are over-picked. In addition, the decrease in the number of people picking reduces the immediate need for regulations to be implemented.

- A closed season and/or a minimum landing size were both discussed as potential regulations to control over-picking. When asked, pickers and wholesalers were in favour of a summer closed season. This coincides with the time of year when there is little harvesting, as prices are low, and pickers become involved in fishing, farming or tourist related industries. However, a closed season during the summer would be of little benefit to periwinkle stocks. A closed season that coincides with the spawning period of *L. littorea* (possibly January to April, pending conclusive research that this is the spawning period for most Irish populations) would appear to be one of the best options for ensuring the protection of periwinkle populations. It is less likely that pickers and wholesalers would support a closed season at any time of the year other than during the summer.

- If the implementation of regulations becomes necessary in the future, a closed season would be the best management option to consider.

- Over the duration of this project, larval rearing trials were carried out at the Shellfish Research Laboratory, Carna. During the course of this work, it was found that the spawning season at Carna, County Galway extends from January to April/May. The spawning season is known to vary geographically, so further research needs to be carried out to establish the spawning season for Irish *L. littorea* populations.

- A minimum landing size of 13mm was suggested by many of the wholesalers. This corresponds with the smallest sized periwinkle that would be acceptable on the general market, and fails to take age/size of maturity into consideration. It must be noted that, in Galway Bay at least, some periwinkles do not mature until they are 15-17mm shell height. This means the minimum size advocated by wholesalers might not protect the species as desired.

- Widespread reports of over-picking must be considered in the context of the decline in the number of commercial harvesters involved in the industry, and this should be taken into account before any consideration is given to introducing regulations.

6.1.4 The future of the industry

- The future of the periwinkle industry in Ireland may be heavily dependent on the future economic climate of the country. If economic growth continues or at least stabilises at its present level, then the main threat to the industry will be the lack of harvesters to ensure a continuity of supply.

- The lengthy planktotrophic stage of *L. littorea* makes it less subject to the effects of localised overexploitation than species without such ability to disperse. Where populations of large periwinkles are removed from one area, larvae can be recruited from more distant shores, and so, in time, over-picked areas may be re-seeded. The periwinkle fishery in Ireland has withstood the test of time and has almost certainly come through periods of very intense picking pressure in the past (as shown by periwinkle landing data from the 1903 Browne Report).

- The potential for adding value to exports by post harvest processing appears to be limited. A fresh live periwinkle is the product most sought after on the continent, especially France.

- At certain times of the year, the demand for periwinkles is so high that the supply does not satisfy the demand from foreign markets. During periods of peak market demand, Irish wholesalers could export greater quantities of periwinkles if more periwinkles were picked or available. Developments in on-growing and polyculture could provide areas of future growth for the industry. In the future if prices should rise as a consequence of a decline in supply, ongrowing and polyculture may become economically viable. There is also potential for selling more periwinkles to Irish seafood restaurants, particularly during the tourist season.

6.2 Recommendations

- It must be appreciated that this report is a baseline study of the periwinkle industry carried out over a short time frame. Thus it would be unwise to make any immediate long term predictions or assumptions or to precipitate untimely protective measures without the benefit of ongoing data to demonstrate or validate their necessity.

- On the basis of this study no immediate action appears to be required in regard to protective legislation for periwinkles either by closed season, catch or size limitations or closed/protected areas.

- Periwinkle stock status should be continually reviewed and updated from strategically located key sites where calibrated sampling should be structured to include estimates of natural and fishing mortality, catch per unit effort, (CPUE), as well as overall trends in population composition. Thus, in the event of any untoward alteration in any of these parameters, rapid remedial action could be decided based on the updated predictive model. Such data could be used to counteract long-term effects due, for example, to overfishing, poor recruitment etc. by carefully selected legislation.

- Complementary investigations should also be undertaken to determine seasonality in spawnings for populations around the coast, as well as development of methods to predict yield per recruit, and thus determine relative year class strengths as a component for long term yield predictions. Also without such knowledge it is impossible to identify closed seasons in the event they might be necessary to protect adults during the spawning season.

- It may be that inaccessible periwinkle populations have historically acted as a reservoir to ensure regular recruitment into exploited areas of the fishery. If fishing pressure increase significantly it is suggested that an extended protection of such areas may be a logical management option which would be more readily supported by the industry than other alternatives.

- Should a requirement emerge in the short term requiring protective measures relating to season or size, these would have to be unilateral as any such local regulations would prove very difficult to enforce due to the movement patterns of post harvest stock.

- Developments in on-growing and polyculture could provide areas of future growth for the industry. Interest in these was expressed during the survey and it is recommended that government agencies take a more pro-active role in encouraging feasibility trials in this area, as there is currently little support or expertise available on the subject.

- There is potential for selling more periwinkles to Irish seafood restaurants, particularly during the tourist season. Fears about the safety of eating periwinkles contaminated by pollution need to be allayed and seafood chefs need to be made aware of where to obtain local supplies.

- It should be noted that the periwinkle may be well suited to demonstrate the operation, practices and benefits which can derive from understanding the biology and population dynamics of a species. It might be an appropriate case study as an example for other inshore commercial species and additionally could provide opportunities for and benefit from post graduate research as well as "hands on" experience and training in applied fisheries practices.

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Appendix A. The Lewis Biological Exposure Scale Defined (Lewis, 1964)

1. Very Exposed Shores

i. A very wide *Verrucaria* belt *entirely* above tidal level, and reaching perhaps 40-60ft. or more above the barnacle line.
ii. *Littorina neritoides* abundant throughout the lower *Verrucaria* zone; density varying greatly with substrate but not less that 1 per 5 $cm.^2$ on open surface, or 5-10 per sq. cm. in crevices.
iii. *Porphyra*/Myxophyceae belts well developed above the barnacle line persisting throughout the summer in the north, especially on flatter slopes.
iv. *Fucus distichus anceps,* and *F.sp*. f. *nanus* present (in the north and west).
v. *Lichina pygnaea* locally abundant (especially on verticals and in the south) and covering 20-40% of surface at level of maximum density.
vi. Eulittorial zone dominated by barnacles and limpets (with minimum densities of 100-150 per 5 $cm.^2$ and 50-100 per sq. metre respectively), or by *Mytilus*/Rhodophyceae communities which cover at least 50% surface in levels of maximum density.
vii. *Patella aspera* the dominant limpet in the middle and lower shores
viii. A belt of lithothamnia/*Corallina* and other Rhodophyceae usually present above the *Alaria* zone when the midshores lack *Mytilus*/Rhodophyceae communities.
ix. The upper sublittoral zone dominated by *Alaria*/lithothamnia and *P. aspera* and rising to M.L.W.N or above.

2. Exposed Shores

i. A *verrucaria* belt 10-30 ft. wide, largely above tidal levels.
ii. *Littorina neritoides* abundant, some *L. saxatilis* present.
iii. Some development of *Porphyra*/Myxophyceae belts (especially in north).
iv. *Lichina pygmaea* abundant (especially in the south).
v. Midshores dominated by barnacles and limpets alone, or by barnacles, limpets and *F.v.* f. *linearis* in flatter areas; the latter ranging from scattered solitary plants (especially in the south) to 50% cover or more (especially in the north).
vi. *Mytilus*/Rhodophyceae communities local, rarely dominant; most common in north and west.
vii. *Patella aspera* abundant in lower shore.
viii. *Thais lapillus* abundant; groups of several hundreds, or a scattered density not less than 10-20 per sq. metre.
ix. Well-developed belt of *Himanthalia* and /or Rhodophyceae (*Gigartina, Corallina* especially).
x. Some *Balanus perforatus* possible in S.W. England and *Bifucaria* in S.W. England and Ireland.
xi. The upper sublittoral zone dominated by *Alaria* in north, *Alaria* and *Laminaria digitata* in south.

3. Semi-Exposed Shores

i. *Verrucaria* belt about 4-10 ft. deep, partly within reach of the tides.
ii. *Littorina saxatilis* dominant, astride lower limit of *Verrucaria; L. neritiodes* becoming scarce especially in north.
iii. Distinct belts of *Pelvetia* upshore and/or *Fucus serratus* downshore (especially on flatter surfaces).
iv. *Chthamalus stellatus* becoming scarce (in north-west and west).
v. *Lichina pygmaea* present but zone barely detectable.
vi. Midshores of mixed barnacles, limpets and short *Fucus vesiculosus.*
vii. *Monodonta lineata* and *Gibbula umbilicalis* present (in south and west); 1-5 per sq. metre, more locally, especially near pools.
viii. *Thais* present and *L. littorea* appearing but local density varying greatly with topography.
ix. *Fucus serratus* belt associated with or surmounted by Rhodophyceae *(Laurencia* spp., *Gigartina, Rhodymenia, Lomentaria*); locally replaced by *Balanus perforatus* especially on verticals or in shade.
x. *Patella aspera* present but largely confined to lower littoral and sublittoral zone, or to lithothamnia pools.
xi. *Laminaria digitata* and lush growths of small algae dominate the sublittoral; *Saccorhiza polyschides* locally abundant in south and west.

4. Sheltered Shores

i. *Verrucaria* zone narrow and within reach of waves.
ii. *L. saxatilis* abundant (50-100 per sq. metre at least) when upper fucoids scarce.
iii. Full sequence of fucoid zones *(Pelvetia, F. spiralis, Ascophyllum* and/or *F. vesiculosus, F. serratus*), but cover not sufficiently dense to exclude barnacles completely.
iv. Barnacles, usually large, thinly scattered or patchy except on verticals.
v. Abundance of *Littorina littorea* and *L. obtusata* on all coasts, and of *Monodonta* and *Gibbula umbilicalis* in south and west.
vi. *Patella vulgata* abundant; *P. aspera* scarce or absent.
vii. *Laminaria digitata* dominate in the upper sublittoral zone.

5. Very Sheltered Shores

i. Extreme compression of *Verrucaria* zone to a 1-3 ft. belt lying *entirely* within reach of spring tides.
ii. Complete dominance of fucoids, and especially of long fronded *Ascophyllum* (4-12 ft. or more).
iii. Extreme scarcity of barnacles, except on some verticals, and their upper limit usually below M.H.W.N. (especially in *Balanus* areas).
iv. A well-developed *Catenella/Bostrychia*/Myxophyceae belt (especially in south and west).
v. The sublittoral zone dominated by *L. saccharina/Halidrys* with a *Chondrus/Furcellaria*

Appendix B. Periwinkle GIS Operations Manual for the Marine Institute

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Background to the Periwinkle Project

The edible periwinkle *Littorina littorea* has been exploited as a food source in Ireland since the stone age (Woodman, Anderson, Finlay, 1999). Today there is a large market for the edible periwinkle on the continent, principally in France. The edible periwinkle industry remains a fishery of socio-economic importance in peripheral coastal communities. It is particularly important as an additional source of income in areas where few other employment opportunities exist.

Prior to this study, there was little or no scientific information available on the state of Irish periwinkle stocks, nor was there an accurate estimate of the scale and value of the Irish industry. This project aimed to redress this situation significantly.

The main objectives of the Periwinkle Project were:

- To establish the distribution, size and age distribution of the edible periwinkle populations along the Irish coast.

- In reviewing the Irish periwinkle industry, to assess its socio-economic impact on Irish coastal communities and to determine the potential impact of developments within this sector.

- **To incorporate the resultant data into a Geographical Information System (GIS). The GIS would then be used as a decision making tool in developing a management strategy for the industry.**

Further details on the Periwinkle Project can be obtained from:

The Marine Institute
80 Harcourt Street
Dublin 2

Information is also provided on:
www.cmrc.ucc.ie/pages/research

This section provides an overview of the GIS database that was completed for the project. Operation of the GIS is explained within the context of this document.

Introduction to (GIS)

GIS stands for Geographical Information Systems. GIS has been compared to the high tech equivalent of the map. The first GIS, which emerged in the early 1980s, allowed for the basic overlaying of geographically referenced data onto digital maps. Since then, these computer systems have developed rapidly in functionality, and can now facilitate the assembling, storing, manipulating, and displaying of a wide range of spatial and temporal data. The capabilities of GIS can broadly be categorised as follows: map production, data retrieval, data warehousing, report generation, data modelling, data integration, data transformation to a common projection and data overlays. There are several different types of GIS software packages available. MapInfo, GeoMedia and ArcView are amongst some of the more popular GIS packages used in this country. ArcView was the package used for this project as this software was already in place in the Coastal Resources Centre, UCC, where there is a large amount of expertise in using this system for the mapping of natural resources and other coastal data.

Data Capture Methods

During the project, 124 shore surveys were carried out. The bulk of the data held in the GIS originates from these surveys. Survey sites were selected on the basis that they provide suitable habitats for harvestable quantities of periwinkles; these were usually sheltered or semi-exposed shores. Other sites may have been selected (e.g. exposed coasts) for comparative purposes.

Three belts of approximately 30m width were divided into three biologically defined zones representing upper, middle and lower shores. (i) *Fucus spiralis* to *Ascophyllum nodosum*; (ii) A. *nodosum* to *F. serratus;* (iii) *F. serratus* to the low water level. Exposure was rated on a scale of one to five (after Lewis, 1964); one represented extremely exposed sites, and five represented very sheltered sites. In some cases, the exposure scale was subdivided to allow more flexibility in describing shores. As a result, there were ten possible degrees of exposure i.e. 1, 1.5, 2, 2.5 etc. Five quadrats ($0.25m^2$) were placed randomly within each zone and all the edible periwinkles, *L. littorea,* within each quadrat were counted, removed, and placed in labelled polythene bags. The samples were returned to the laboratory and kept in freezers to preserve them for further analysis.

The percentage cover of rockpool, seaweed, bedrock, rock, stones, gravel, sand and mud were also recorded from each quadrat. Any influx of freshwater into the belt, or any other potential impact from sewage or shellfish culture was noted.

The length of each of the three belts was measured and the bearing of each was also noted. A handheld Global Positioning System (GPS) was used to mark the starting point of each belt, in addition to the start and end point for each site. This, and other relevant data were subsequently added to a Geographical Information System (GIS).

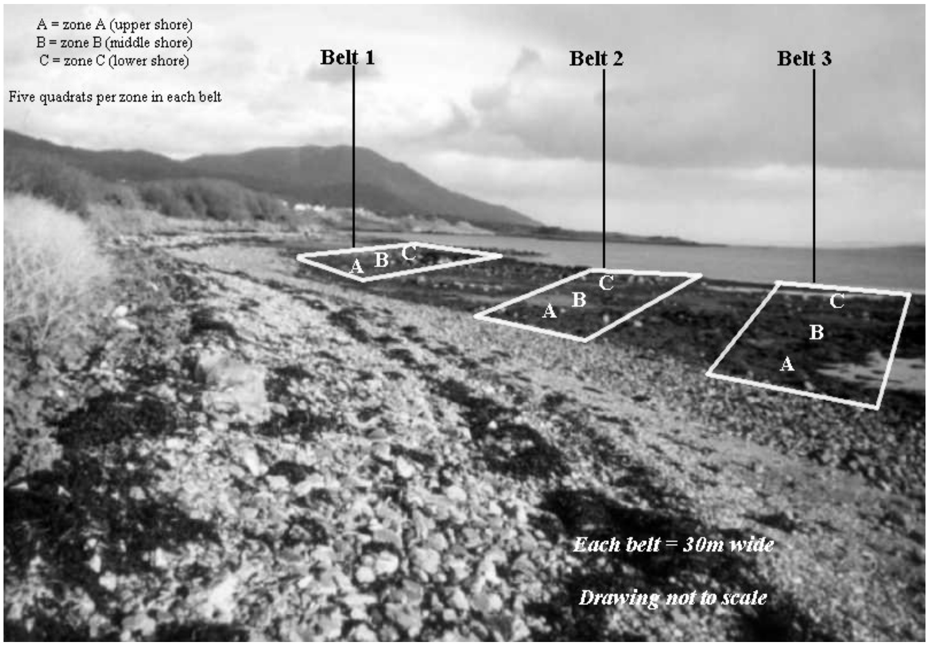


Figure 1. Sampling procedure carried used on the shore

Overview

The results from the shore surveys identify the areas of our coastline that are currently harvested for periwinkles. Results show periwinkle densities at these locations, and the average size of periwinkles measured at selected sites, taken from nearly 22,000 measurements of shell size. Additional data collected from individual sites were also included. The GIS facilitated the production of resource maps at various scales, with colour coded labels for additional attributes. These maps were used in the production of the final report.

Additional data layers were also added to the GIS from other sources. For example an outline of the coastline of Ireland, plus the county boundaries provide the backdrop for most of the information. Data from the Ordnance Survey 1:50,000 digital maps, such as roads, car parks and urban areas, were also added. This was obtained from the Marine Access Project, (completed by the Coastal Resources Centre for the Marine Institute), which contains the location of piers and jetties all around the country.

A project to map and assess the seaweed resources (*Ascophyllum nodosum, Laminaria spp.*) off the West Coast of Ireland was conducted in 1998 (Hession, Guiry and Joyce, 1998). This database was also incorporated into the Periwinkle Project GIS as another data layer.

The Periwinkle Project GIS can be interrogated to provide information on all aspects of the industry as described above. The flexibility of these computer systems means that future data can easily be incorporated, thus providing decision-making bodies with a powerful management tool.

Getting Started

Insert the CD entitled "Periwinkle Project GIS". The project information is stored on the CD in the D drive, in the 'winkle' folder. Select the 'winkle' folder, copy it, and paste it to your C drive. It is preferable that the periwinkle GIS is installed as C:\winkle. If it is installed under a different path, then you will need to make changes to your startup settings in Arc View[1].

Open ArcView by going to Start – Program – Esri – ArcView GIS. When ArcView has loaded, go to file and click on open project. Select C:\winkle\winkle.apr (this is the project file). Wait for a couple of seconds for the project to open. The project will open in a **VIEW WINDOW**. An outline of the Irish Coast and County Boundaries will become visible in the **map display**. These are **themes** and the visible themes are listed in the **table of contents** to the left of the map display. These themes are **ticked** to show that they are turned **on**.

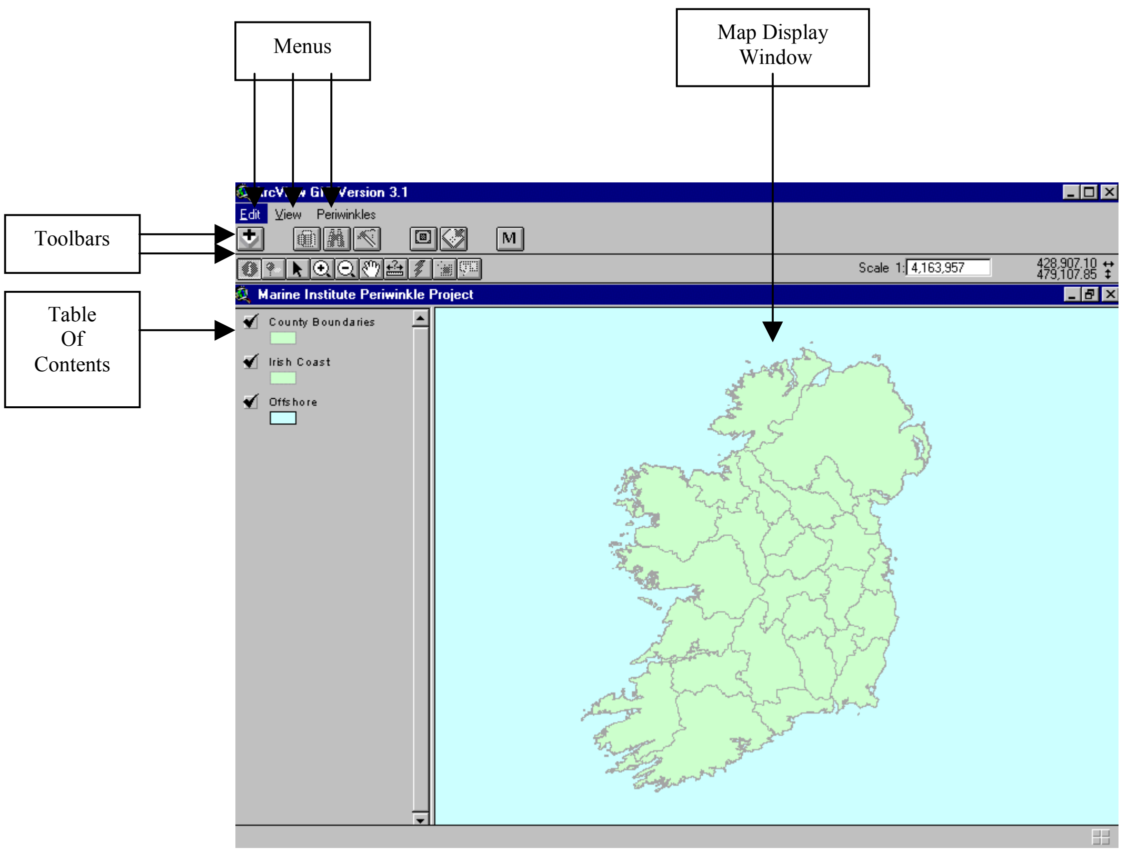


Figure 2. Overview of the first view to open in the periwinkle GIS.

[1] To install the periwinkle GIS under an alternative path to C:\winkle, go to C:ESRI\AV_GIS30\ARCVIEW\ETC\Startup. Select the Startup File (not the PS File). Open this file in Wordpad. Scroll down to the bottom of the text, to where it says: System.SetEnvVar("DATADRIVE","C:\winkle\"). Change the datadrive details to the new path where the periwinkle GIS will be installed.

Structure of the GIS - (Themes and Topics)

The data was grouped into six different **topics**, which made up six different data layers on the GIS. The topics are basically the subject areas into which the data are divided. The topics are: survey information, industry information, morphometric data, topographic data, seaweed data, bathymetry. Each of these topics contains a range of **themes**, which can be added to the table of contents and viewed in the map display where they will be displayed as lines, points or polygons, depending on the type of data. Table 1 shows a breakdown of each topic and theme.

Topic	*Sub Heading*	*Theme*
Site Information	Survey Information	Access to Sites
		End of survey site
		Exposure
		Harvested sites
		Rockpool coverage
		Rugosity
		Seaweed coverage
		Start of survey site
		Substrate type
		Winkles per m2
	Belt Data	Belt locations
		Freshwater impact
		Winkles per quadrant
	Site Photographs	Site photographs
Industry Information		Wholesalers
Morphometric Data	Shell Measurements	Maximum shell height
		Mean aperture width
		Mean shell height
		Mean shell width
Topographic Data	OS 1:50,000 Discovery Series	Beaches
		Coastal features
		High water mark
		Low water mark
		Piers, slips, jetties
		Place-names
		Rivers
		Roads
		Tourist features
		Urban areas
Seaweed Database		Seaweed data
Bathymetry	Admiralty Chart Data	Contours
		Grid derived from spot depths

Table 1. Themes and Topics in the GIS

Viewing the Data

The Periwinkle Project GIS was saved into a customised version of ArcView, with many of the more advanced functions removed. As a result, the data can be viewed by anyone with basic computer skills, and expertise in GIS is not required to access the data. To view a theme, simply click on the Periwinkles Menu. A drop-down menu will appear. Select the topic of interest. Another menu will appear which shows a list of the themes available for that topic. Highlight the themes that you would like to add and click okay. You are now on your way to accessing the data held in the GIS. The various menus and toolbars are outlined below.

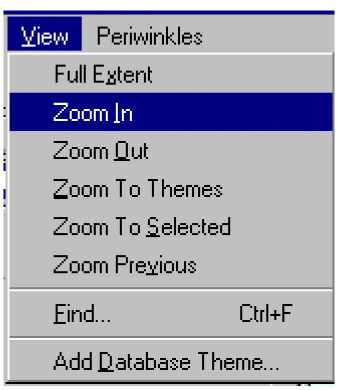
1. Menus

There are three main menus, which are primarily for viewing the maps at different scales, and adding and removing themes and topics. They are the Edit, View and Periwinkles menus.

The Edit Menu

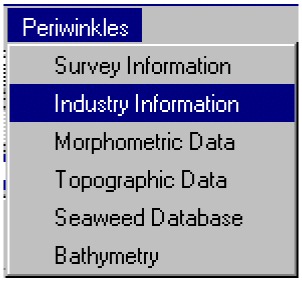
- to delete themes or to delete entire topics from the table of contents

The View Menu



- to view the full extent of the map
- to zoom in or out of specific areas of the map display
- to find a particular name on the map e.g. place name
- to add a new theme from an external database using SQL

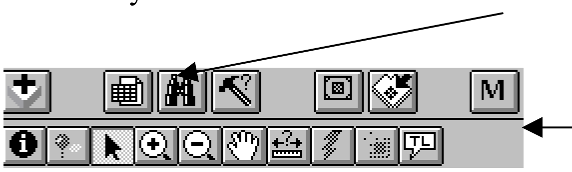
The Periwinkles Menu



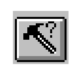
- to add a new theme to the table of contents. Themes are organised under the six topics described in table one.

2. Toolbars

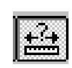
Toolbars provide shortcuts to many of the functions described above. For example, the binoculars symbol is a shortcut to the **Find Tool.**



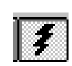
These are all of the tools that can be used in the project window



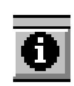
The **Query Builder** allows you to design your own queries of the data. By default, the query is contained within parentheses, but the parentheses may not be required, depending on the complexity of your query.



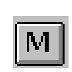
It is also possible to **Measure** the distance between one point on the map and another. A choice of units is available for display e.g. meters, miles, kilometres etc.



HotLinks let you access virtually any data or application directly from a view. For example, you can click on a site to display a photograph of the surveyed belts. A hot link is followed when you click on a feature in a theme with the HotLink tool.



The **Identify Tool** can be used to provide attribute values for an **Active Theme** (click on the theme in the table of contents to make it active; – notice that it will appear raised above the other themes).



The **Metadata Tool** provides background information on the origin of a selected data-point

Screenshots

The following screenshots provide an insight into how some of the data appears in the GIS.

- **Detailed large scale maps**

It is possible to zoom into a specific area for a more detailed view. Below is an example of the Donegal Coastline with themes containing information on seaweed coverage, coastal features, county boundaries and bathymetry. Results of a query on a seaweed coverage datapoint are shown in the 'Identify Results' dialogue box. The scroll down bar on the right of the table can be used to show the rest of the results.

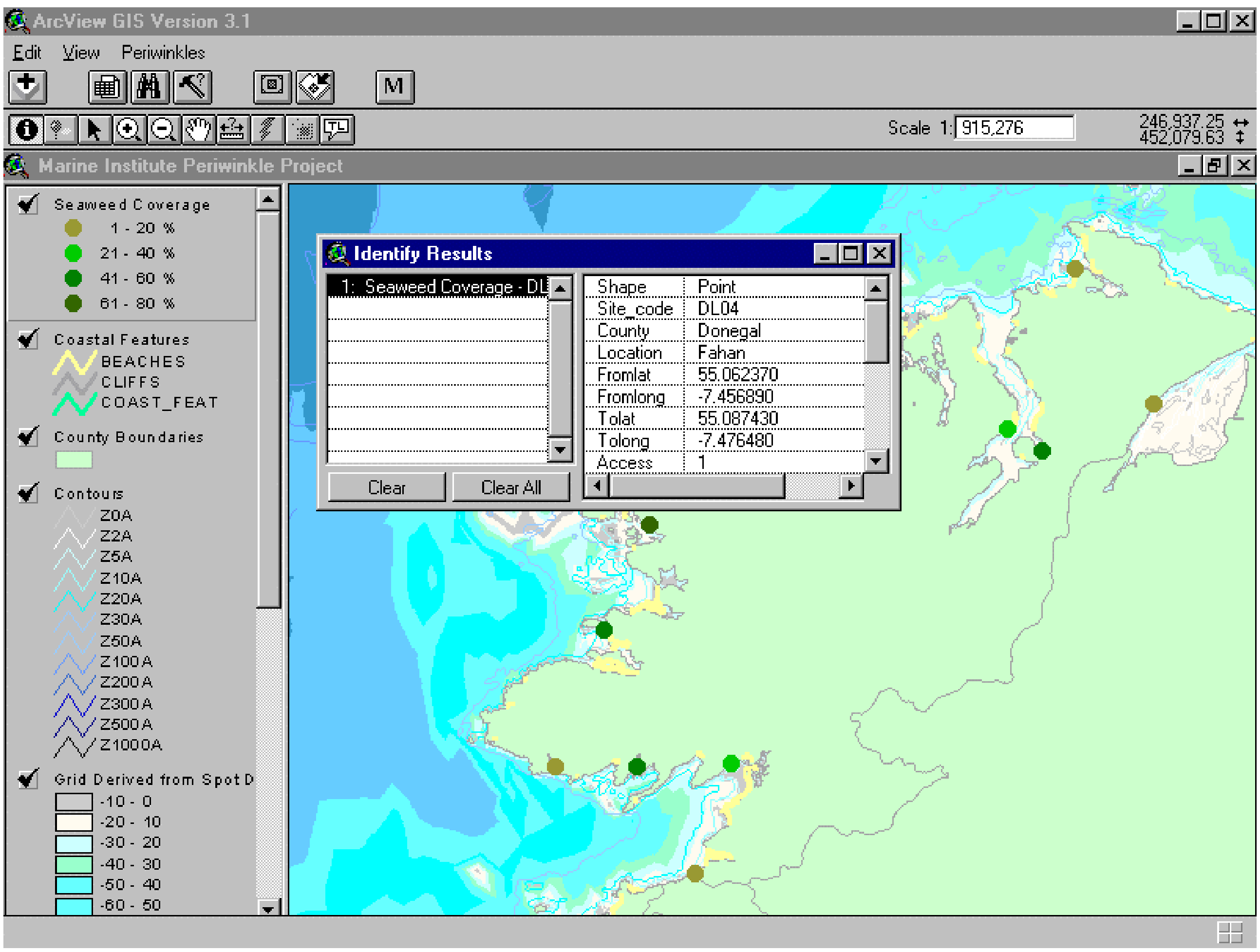


Figure 3. An example of a detailed large scale map.

- **Periwinkle density maps**

Polygons showing the length and bearing of each belt are colour coded to show periwinkle densities per zone. This information was reproduced to scale. In figure 4 the periwinkle densities are less than 40 per m^2 (shaded light pink) in all of zones A, B and C. The position of the start and end points of the shore are shown as red points.

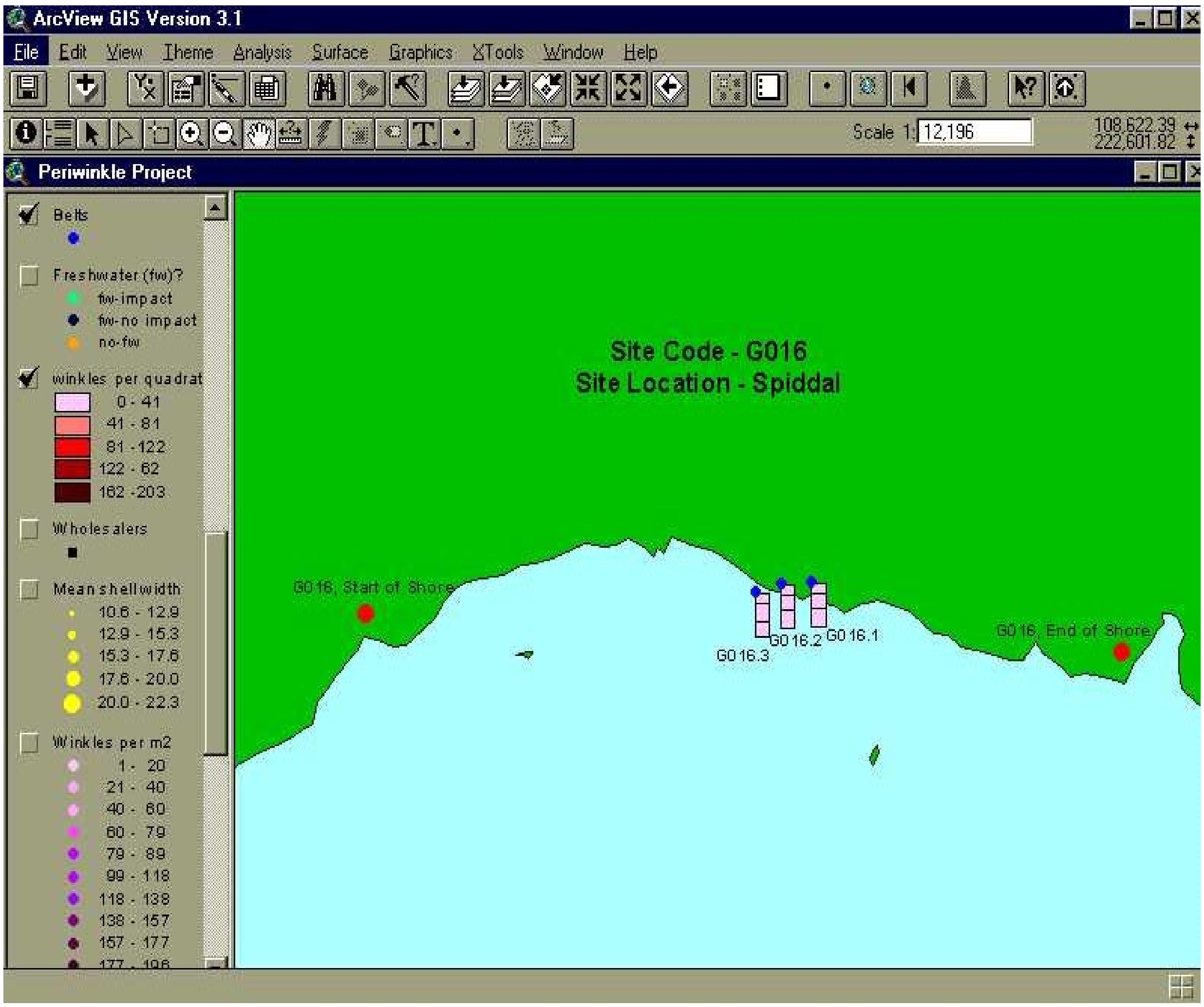


Figure 4. An example of a periwinkle density map.

The Project Window

Everything that has been described up until this point would have been viewed in the **VIEW WINDOW** mentioned earlier. Simply simply closing or minimising the View Window can access the PROJECT WINDOW. You will notice that a different set of menu bars will appear along the top. These menus are similar to those used in many Windows environments e.g. File - Close. There is also a **Help** option here, which provides information on all aspects of Arc View.

The layout of the **Table of Contents** will also look different. There will be a list of options including:Views, Tables, Layouts, Scripts and Dialogues. Only the **Views** and **Tables** options are needed here. Clicking on Views, highlighting Marine Institute Periwinkle Project and selecting Open will return you to the View Window. The Metadata Table can be viewed by selecting the Tables option. This is explained below.

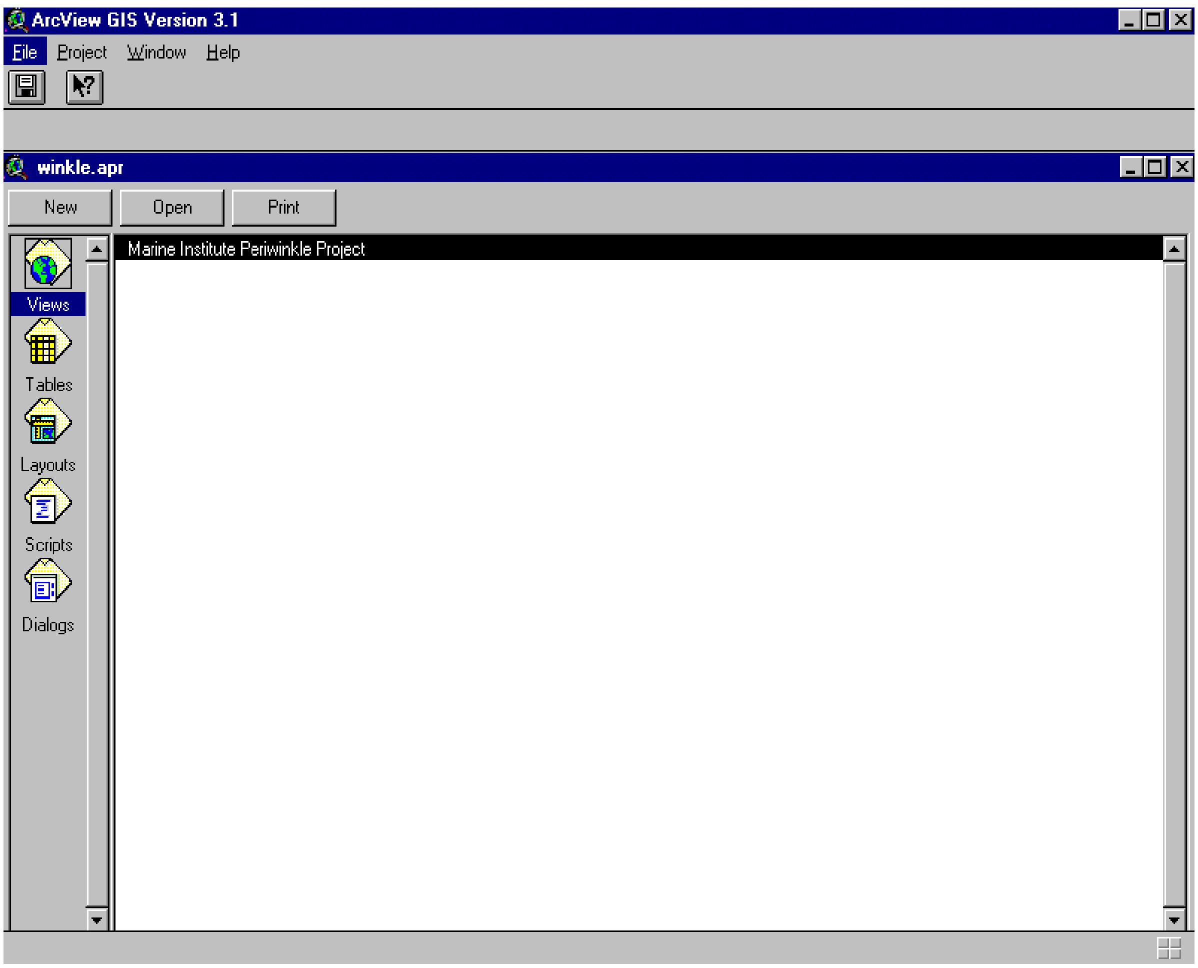
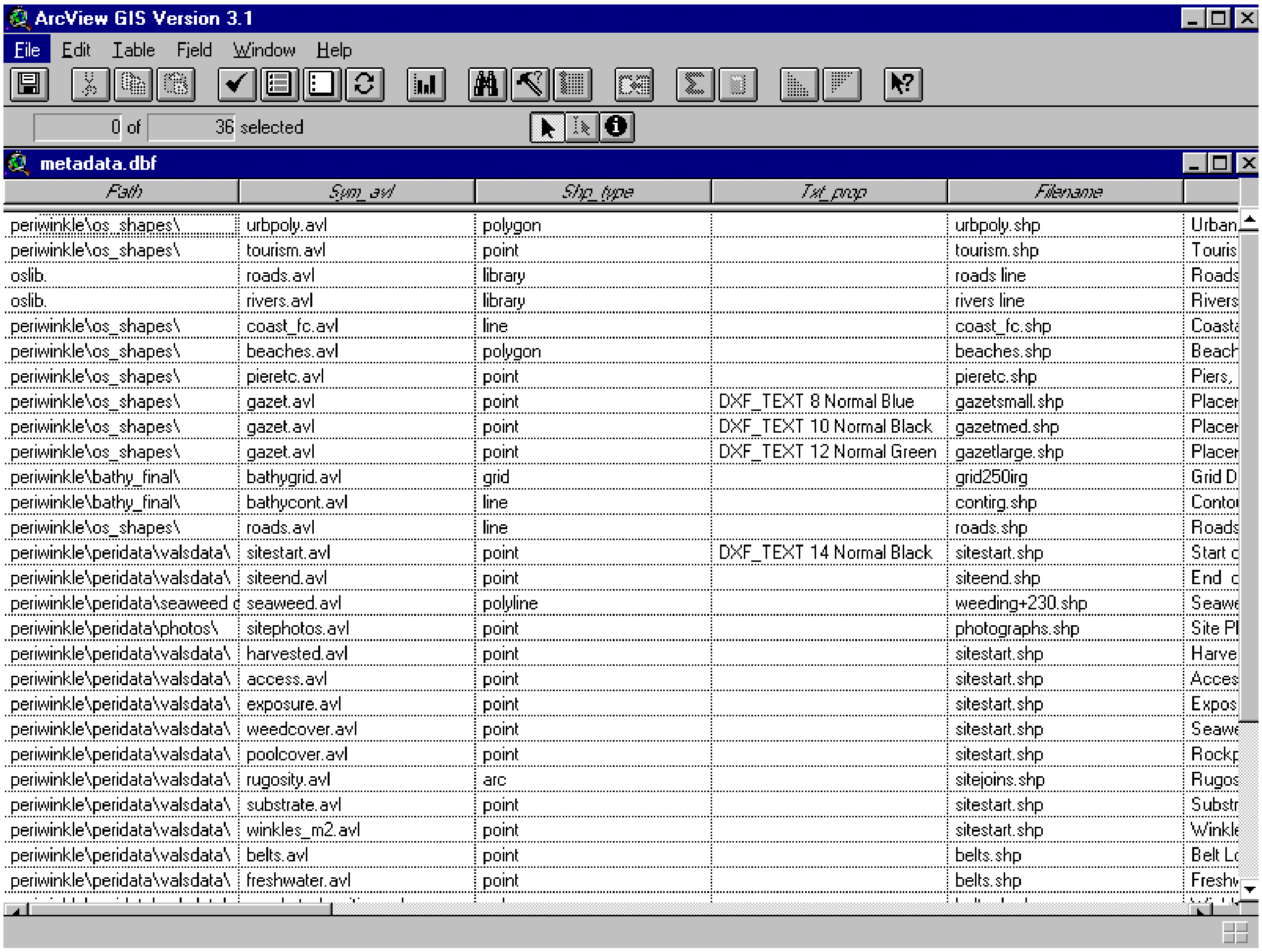


Figure 5. The project window.

The Metadata Table

To open the **Metadata Table**, click on **Tables** from the **Table of Contents** in the **Project Window**. The Metadata Table contains background information on individual files, such as the file path, the filename, the legend, copyright, scale, source etc.



Path	Sym_avl	Shp_type	Txt_prop	Filename	
periwinkle\os_shapes\	urbpoly.avl	polygon		urbpoly.shp	Urban
periwinkle\os_shapes\	tourism.avl	point		tourism.shp	Touris
oslib.	roads.avl	library		roads line	Roads
oslib.	rivers.avl	library		rivers line	Rivers
periwinkle\os_shapes\	coast_fc.avl	line		coast_fc.shp	Coast
periwinkle\os_shapes\	beaches.avl	polygon		beaches.shp	Beach
periwinkle\os_shapes\	pieretc.avl	point		pieretc.shp	Piers,
periwinkle\os_shapes\	gazet.avl	point	DXF_TEXT 8 Normal Blue	gazetsmall.shp	Placer
periwinkle\os_shapes\	gazet.avl	point	DXF_TEXT 10 Normal Black	gazetmed.shp	Placer
periwinkle\os_shapes\	gazet.avl	point	DXF_TEXT 12 Normal Green	gazetlarge.shp	Placer
periwinkle\bathy_final\	bathygrid.avl	grid		grid250irg	Grid D
periwinkle\bathy_final\	bathycont.avl	line		contirg.shp	Contou
periwinkle\os_shapes\	roads.avl	line		roads.shp	Roads
periwinkle\peridata\valsdata\	sitestart.avl	point	DXF_TEXT 14 Normal Black	sitestart.shp	Start c
periwinkle\peridata\valsdata\	siteend.avl	point		siteend.shp	End c
periwinkle\peridata\seaweed d	seaweed.avl	polyline		weeding+230.shp	Seawe
periwinkle\peridata\photos\	sitephotos.avl	point		photographs.shp	Site Pl
periwinkle\peridata\valsdata\	harvested.avl	point		sitestart.shp	Harve
periwinkle\peridata\valsdata\	access.avl	point		sitestart.shp	Acces
periwinkle\peridata\valsdata\	exposure.avl	point		sitestart.shp	Expos
periwinkle\peridata\valsdata\	weedcover.avl	point		sitestart.shp	Seawe
periwinkle\peridata\valsdata\	poolcover.avl	point		sitestart.shp	Rockp
periwinkle\peridata\valsdata\	rugosity.avl	arc		sitejoins.shp	Rugos
periwinkle\peridata\valsdata\	substrate.avl	point		sitestart.shp	Substr
periwinkle\peridata\valsdata\	winkles_m2.avl	point		sitestart.shp	Winkle
periwinkle\peridata\valsdata\	belts.avl	point		belts.shp	Belt Lo
periwinkle\peridata\valsdata\	freshwater.avl	point		belts.shp	Freshw

Figure 6. The metadata table.

The Accuracy of the GIS

Positions of sites and belts were obtained using a handheld GPS, which is accurate to within 12m. The accuracy of a reading depends on the ability of the receiver to receive enough satellite signals to calculate a position. In some cases the belt positions will appear to overlap with the land. This is due to inaccuracies in the waypoints, and to minor discrepancies in the actual base map outlining the coastline.

Abbreviations used in the Data

Table headings are limited in character length in ArcView. As a result many headings were abbreviated. The abbreviations can be seen when looking at an Attribute Table or when looking at the results of an **Identify** Query.

Qu =	Quadrat
S =	Site
B =	Belt
Z =	Zone
H =	Shell Height
Av_no_ZA =	Average number of periwinkles in Zone A
Av_no_ZB =	Average number of periwinkles in Zone B
Av_no_ZC =	Average number of periwinkles in Zone C
Av_Qu_S =	Average number of periwinkles per quadrat per site
Av_m2_S =	Average number of periwinkles per m^2 per site
Fromlat =	From latitude
Fromlong =	From longitude
Tolat =	To latitude
Tolong =	To longitude
Max _l_s =	Maximum periwinkle shell length per site
Mean_l_a =	Mean shell length in zone A per site
Mean_l_b =	Mean shell length in zone B per site
Mean_l_c =	Mean shell length in zone C per site
Mean_l_s =	Mean shell length per site
Mean_w_a =	Mean shell width in zone A per site
Mean_w_b =	Mean shell width in zone B per site
Mean_w_c =	Mean shell width in zone C per site
Mean_w_s =	Mean shell width per site
Mean_a_a =	Mean shell aperture height in zone A per site
Mean_a_b =	Mean shell aperture height in zone B per site
Mean_a_c =	Mean shell aperture height in zone C per site
Mean_a_s =	Mean shell aperture height per site
Mean_aw_a =	Mean shell aperture width in zone A per site
Mean_aw_b =	Mean shell aperture width in zone B per site
Mean_aw_c =	Mean shell aperture width in zone C per site
Mean_aw_s =	Mean shell aperture width per site

Additional Notes

Zoom in to a scale of a least 1:10,000 to see the belt locations clearly. The belts are recreated to scale (30m wide) which makes it necessary to zoom in to this extent to view them.

Acknowledgements

The project relied heavily on the co-operation and support of many people. The authors would particularly like to thank all the wholesalers who provided information and support for the project. Thanks also to those that assisted in the shore surveys including: David O Regan, Ana Periera, Mary O Connell, Mary-Jo Duncan Ryan, Sandra Leyzour, Magali Molla.

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